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General Astronomy.

PROBABLE ADVANTAGES IN ASTRONOMICAL PHOTOGRAPHY OF SHORT FOCUS LENSES.*

REV. GEORGE M. SEARLE.

According to a formula well known in ordinary terrestrial photography, the intensity of the light received on the plate from any illuminated object, (or, if the illumination of the object be uniform in all its parts, the quantity of light received per square inch) is proportional to the square of the quotient resulting from the division of the diameter of the stop, or of the lens, if a simple combination be used without a stop, by the focal length. This formula plainly follows from the considerations that the total light received by the lens from a given angular area (say of sky), is proportional to the area of the lens, and that this light is distributed on a surface proportional to the square of the focal length.

It follows from this, that if the plates and development are the same, the same intensity (say of sky) will be obtained in photographs taken with the same exposure, and with lenses having the same proportion to their focal lengths, whatever the absolute dimensions of the lenses may be.

Within certain limits also we may assume that the intensity developed on the plate will be under the same circumstances proportional to the exposure, though it is well known that a limit can easily be reached, sooner of course for a brighter object than for a fainter, at which further exposure ceases to be useful, and becomes indeed injurious; and also that some time before this limit, the exposure is less of a factor than before.

Also we may assume, in the same way with due limits, that the intensity developed on a plate with the same exposure is proportional to the square of the quotient which has been given; and hence in general, that the intensity or strength of the photograph will be as the exposure multiplied by the square of this

* Communicated by the author.

quotient; and hence that if we desire, as is the case in terrestrial photography, to produce for instance in the sky an intensity which is the best for the balance of the picture, the exposure should be proportional to the inverse square of the quotient.

If then we photograph the sky with two telescopes, one having for instance, a twelve inch lens with a fifteen foot focus, the other a six inch lens with a three foot focus, the exposure to obtain the same density with the same plate and the same development needs to be only $\frac{36}{225}$ in the latter case of what is required in the former. And the sky will have to be $\frac{225}{36}$ as bright for the twelve inch as for the six, to be photographed in the same time. This is commonplace, everyday photography.

So far we can be reasonably sure of our results. But how can they be applied to stellar photography?

According to abstract theoretical considerations, the intensity of the light of the stars, if there be no absorption of light in space, is proportional to the intrinsic brilliancy of their surfaces, and is the same, no matter to what distance they are removed. Remove the Sun to a million times its present distance and it will look one trillionth part as bright as now; but its disc will be reduced in the same proportion.

If then the intensity of the light is the same, it would seem that all stars of the same intrinsic brilliancy should be photographed in the same time with the same telescope; and also that in this same time they would be photographed by all telescopes having the same proportions of diameter and focal length. Moreover, that time would be accessively short, as the time required for photographing the Sun itself is.

These conclusions, however, are evidently false, being contrary to experience. Why are they false? What theoretical reason can be given?

One is quite obvious. It is that the images or, as they are called, spurious discs, of stars in a telescope are not proportional to the apparent magnitudes of the stars themselves. On this condition which is verified in terrestrial photography, our conclusions of course depend. Take twice as much sky, giving twice as much light, and in the same camera, it covers twice as much plate. But owing to various causes the cone of rays does not come exactly to a point, even if emanating from a point. If we suppose a star to subtend an angle of $0''.01$, as the Sun would, if removed to about 200,000 times its present distance, its image ought to cover a disc on the plate of a diameter of about $\frac{1}{20000000}$ part of the focal length; if the latter be twenty feet for

example, the image should be about $\frac{1}{100000}$ part of an inch broad. Now according to Dawes, the spurious disc of a star in a telescope of twenty feet focus, which we may perhaps assume would have a fifteen inch object-glass, would be $0''.3$, or about $\frac{1}{700000}$ part of the focal length in diameter; that is $\frac{1}{35000}$ part of a foot or $\frac{1}{3000}$ of an inch. The effect on it, therefore, of the actual dimensions or of the nearness of the star is quite inappreciable. Hence at least as long as we use the same telescope, the common formula of photographs has no application to the stars. The images of all stars being practically of the same size in the same telescope, the intensity of their illuminations is simply proportional to the whole light received, or to the apparent quantity of light given by the star; and the exposures will be approximately in the inverse ratio of that light; and the spurious disc being so much larger than the theoretical image of ordinary photography they all require quite a rather long exposure. The Sun, or any other illuminated surface of perceptible dimensions, photographs quickly, because the spurious discs formed by each point of its surface, overlap and strengthen each other; but the star has no such advantage.

The figures given by Mr. Dawes of course refer to the optical image; but may be taken approximately for the photographic image also.

Now, what will be our conclusion with regard to different telescopes? According to Mr. Dawes, the angular diameter of the spurious disc of a star is inversely as that of the object glass; and therefore, if we keep to one proportion between object glass and focal length, inversely as the focal length; hence it would follow, since the real or linear diameter of the spurious disc is equal to its angular diameter multiplied by the focal length, that this real or linear diameter of the disc, in telescopes constructed on the usual proportions, is the same, say $\frac{1}{3000}$ of an inch in all cases. According to this, then, any telescope will illuminate this constant disc for any particular star with a light just in proportion to the area of its object glass; and the time of exposure for any particular star will be, approximately, inversely as the area of the object glass.

This seems to be the rule usually assumed; and taken with the other previously obtained as to stars of different magnitude, would form a regular guide to exposure on stars in astronomical photography. It is simply that the exposure should be for various stars inversely as the product of their actinic brightness multiplied by the area of the object glass used.

But the question arises whether the diameter of the spurious disc is independent of the ratio of the diameter of the lens to its focal length. If we shorten the focus, keeping the diameter of the lens the same, the disc must, it would seem, be altered; of what nature would the alteration be? Even if the disc is made, on the whole, somewhat larger, as one might naturally expect, still if the light were more concentrated toward its central portion, this ought to be photographically, and perhaps also optically, an advantage. With regard to the latter point, at any rate, experience seems to show that stars are more clearly and sharply visible with short-focus telescopes than with long-focused ones of the same size of objective. The long-focus one magnifies more, of course with the same eye-piece, and ought to stand a higher power; but it is better to see a star sharply, if we want to measure its distance from another, than to have that distance on a larger scale, but not to see the star at all.

It may not be certain that short focus telescopes have this optical advantage, but it is at least possible; and with regard to the photographic image, actual photographic experiments must settle the question better than observation can do for the optical image; for not only can the determination be made more quantitatively, but prejudice is also more removed by them. If experiments show that a satisfactory image is produced on any star in a shorter time with a short focus telescope than with a long focus one of the same diameter, or that with the same exposure a fainter star can be taken by it, its practical superiority, for ordinary purposes, is proved; and probably even for micrometric measurements the disadvantage of smaller dimensions would be more than made up for by the saving of time.

I have heard of a case in which it was stated that a ninth magnitude star was photographed with a telescope of six inches aperture and three feet focus in the same time that was required for a seventh magnitude with a telescope of twelve inches aperture and fifteen feet focus. Now a seventh magnitude star is about 6¼ times as bright as a ninth; and if we take the square of the quotient mentioned in the begining we find that it is for the six inch, $\frac{1}{36}$, and for the twelve inch, $\frac{1}{225}$. According to the ordinary photographic formula then, the exposure with the six-inch should be the same as that with the twelve-inch on an object $\frac{225}{36}$ or 6¼ times as bright. In this case therefore it would seem that the ordinary formula of every day photography would work; still it would probably be too much to assume it as a general law in stellar photography.

But there really seems to be no reason why it should not be the proper formula not only for the Sun, Moon, and larger planets, but also for most nebulas and comets. A nebula a minute of arc in diameter is too large for the consideration of the matter of spurious discs; and there is apparently no reason why it should not photograph according to the same laws as a piece of sky; if so, in this class of work, the superiority of the short focus lens in the matter of exposure would be unquestionable. Its short focus would, of course, make the picture of the nebula smaller; but it can be enlarged, in a few minutes, as much as we please, with a copying camera.

ON A GRAPHICAL METHOD OF DERIVING THE APPARENT ORBIT OF A DOUBLE STAR FROM THE ELEMENTS.*

T. J. J. SEE.

For a long time it has been customary to test the accuracy of double star orbits by comparing the computed with the observed places, and to estimate the value of an orbit mainly by the residuals of position angle. Mr. Burnham's great practical experience with the micrometer has shown that distances (especially in case of close pairs) are quite as trustworthy as angles, and the method of finding an orbit solely by means of position angles has often been discredited by absurd results of computers who discard the measures of distance. That distances should be given more weight in the determination of orbits than has been customary hitherto is sufficiently established by Mr. Burnham's work on numerous stars, and by the researches of Otto Struve on the orbit of 42 Comæ Berenices (*Monthly Notices*,) vol. XXXV, p. 370), which depends almost solely upon distances.

Mr. Burnham has therefore come to the conclusion that the only safe basis for the determination of a double star orbit consists in the use of both angles and distances as given directly by the observers without any correction by means of graphical curves or otherwise.

My own recent experience in the determination of double star orbits confirms the validity of this conclusion. For although we know that the graphical curve of observations will flow smoothly, we never know, and, in the nature of things, never can know what the *curvature* should be at the different points,

* Communicated by the author.

whereas if the observations are platted directly we know at least that the apparent orbit must be an ellipse, which we can easily draw by trial so as to conform to the best observations.

The graphical curve has also the additional disadvantage that it "fixes" the data, and does not enable one to go behind the orbit thus deduced, whereas if the observations are platted directly the trial ellipse may be varied at will; indeed this trial ellipse is the only interpolating curve which is at all satisfactory and it meets the conditions of the problem admirably.

In investigating the orbits of a number of stars, Mr. Burnham has found it desirable to have a short practical method of laying down the apparent orbit from the elements, so that a working astronomer might readily compare the observed places directly with the orbit without going through a long calculation. This desirable result may be obtained by means of the following simple process:

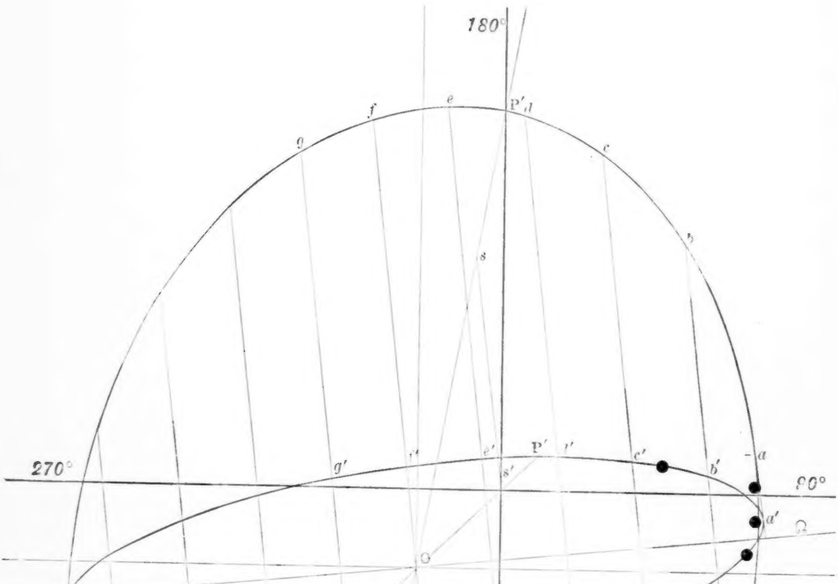
Owing to projection all diameters of the real ellipse will be shortened, except the diameter which coincides with the line of nodes (the line of intersection of the plane of the orbit with the tangent plane of the heavens). From this it follows that if from points on the arc of the real ellipse we let fall perpendiculars to the line of nodes, and shorten these perpendiculars in the ratio of cosine of the inclination to unity, we shall obtain points through which the apparent ellipse must pass; and when 10 or 12 such points have been determined it is an easy matter to draw the apparent ellipse either by means of an ellipsograph or by the free hand. To illustrate this method graphically, I shall apply it to the orbit of 9 Argûs = β 101, as given in the ASTRONOMY AND ASTRO-PHYSICS for June.

The elements of the orbit of this pair which are required for this purpose are the following:

$$\begin{aligned} \text{Eccentricity, } e &= \;\; 0.68 \\ \text{Semi-Major axis, } a &= \;\; 0''.612 \\ \text{Node, } \Omega &= 95^\circ.75 \\ \text{Inclination, } i &= 76\ .87 \\ \text{Node to Periastron, } \lambda &= 73\ .92 \end{aligned}$$

On suitable drawing paper we lay down two lines at right angles to each other, which represent the four quadrants of position angles. The intersection of these lines will be the centre of the real orbit and also the centre of the apparent orbit. The line of nodes is then drawn through the centre, having a position angle of 95°.75. In like manner we lay down the line whose po-

PLATE XXX.



sition angle is $73°.92 + 95°.75 = \lambda + \omega = 169°.67$, and this will be the major axis of the real ellipse.

We now adopt a convenient scale of distances, which will give a distance on the drawing paper of 10 or 12 inches for the major axis.

With close pairs, $0''.1$ may represent one or two inches of the scale, so that the work can be done with the highest degree of accuracy. From the centre the length of the semi-major axis ($0''.612$) is laid down on the line just drawn, and the distance of the foci of the ellipse from the centre will then be ae ($0''.612 \times 0.68$). The ellipse is then drawn in the usual manner.

We now lay off points on the line of nodes at equal distances from the centre of the ellipse, and through these points draw lines aa', bb', cc', dd', etc., perpendicular to the line of nodes. The lengths of these lines on either side are found in seconds of arc by the scale used, and these values multiplied by the cosine of the inclination (cos. $76°.87 = 0.227$); the resulting values are marked on the corresponding lines at a', b', c', d', e', f', etc., on both sides of the line of nodes. These points will lie on the arc of the real ellipse as seen from the Earth, and when we pass an ellipse through these points, we have the apparent orbit of the double star.

To find the position of the star in the apparent ellipse, the distance of the focus s of the real ellipse from the line of nodes is multiplied by the cosine of the inclination as before, and the point s' laid down, which will be the position of the central star as seen from the Earth. A line $Os'P'$ drawn from the centre through this point to intersect the arc of the apparent ellipse gives the position angle of the real major axis, and the position of the real periastron.

Having thus obtained the position of the central star in the apparent orbit, it only remains to draw *through the principal star* lines parallel to those intersecting at the centre and marking the four quadrants, which may now be erased. In the figure the lines through the central star which mark the four quadrants are indicated by heavy lines, so that they are easily recognized.

This very simple process of projection thus enables us to lay down for inspection by the eye the apparent orbit of any star when the elements are properly given; and from the observed positions (indicated in the figure by black dots) we see that the apparent orbit represents the observations satisfactorily. It only remains to add that in case of retrograde motion, the angle λ (which should always be counted in the direction of the motion,

while the ascending node should be taken between 0° and 180°) must for purposes of graphical representation be taken as negative, and the position angle of the major axis of the real ellipse becomes $\Omega - \lambda$, whereas for direct motion the angle is $\Omega + \lambda$, as in case of 9 Argus.

The usage of astronomers as respects the angle λ is by no means uniform, some counting it in the direction of the motion, others in the direction of increasing position angles. Now since it is very difficult to depict an orbit graphically without knowing how λ is counted, it is of the utmost importance that the method of reckoning should be uniform. Therefore I venture to suggest the following means of disentangling the confusion hitherto existing in the elements of double star orbits:

Since in case of double stars we can not distinguish between ascending and descending node, and one node must necessarily fall between 0° and 180°, that node should be taken as the ascending node; then the angle λ and the argument of the latitude u should be counted *in the direction of the motion* from this node. This will remove all obscurity in laying down the apparent orbit, and will also render the deduction of the true anomalies very simple: $v = u - \lambda$ both for direct and retrograde motion. It is here assumed, in accordance with prevailing usage, that the inclination i, never surpasses 90°. In connection with the usual elements, it would be desirable to have also the position angle of the real major axis, and the lengths of the major and minor axes of the apparent orbit. In case of 9 Argus the elements would be:

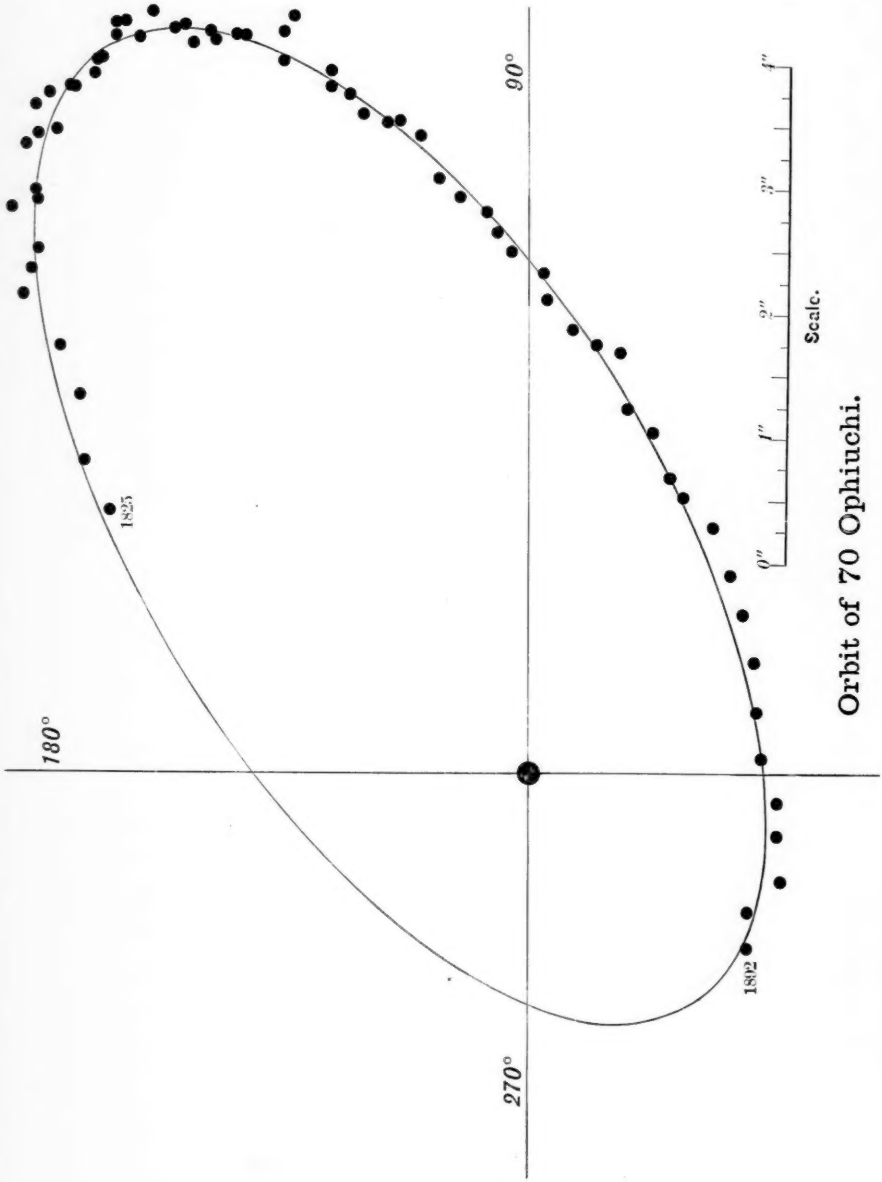
$$
\begin{aligned}
P &= 23.377 \text{ years.} \\
T &= 1892.706 \\
e &= 0.68 \\
a &= 0''.612 \\
i &= 76^\circ.87 \\
\Omega &= 95\ .75 \\
\lambda &= 73\ .92 \\
n &= +\,15.3998.
\end{aligned}
$$

Apparent Orbit:

Length of major axis = 0″.938
Length of minor axis = 0 .276
Angle of major axis = 98°.7
Angle of Periastron = 134 .0
Distance of star from centre = 0″.15

If λ and Ω are correctly given, these supplementary elements

PLATE XXXI.



Orbit of 70 Ophiuchi.

can be derived by simply projecting the orbit as explained in this paper. The agreement of observed distances with the orbit thus derived will be at once evident, while the observed angles may be investigatd by means of the law of areas.

THE UNIVERSITY OF CHICAGO.
1893, June 30.

THE ORBIT OF 70 OPHIUCHI.*

S. W. BURNHAM.

Having made a complete list of the measures of 70 Ophiuchi, I have taken occasion to get the elements of the orbit by the graphical method. How well the apparent ellipse represents the observations will be seen from the accompanying diagram. The positions given are for each year in which complete measures have been made. When measured by more than one observer, a simple mean is taken. The last measures shown are my observations at Mt. Hamilton in 1892.

The following elements are derived from this ellipse :

$$
\begin{aligned}
P &= 87.75 \text{ years.} \\
T &= 1895.6 \\
e &= 0.50 \\
a &= 4''.56 \\
i &= 58^\circ.3 \\
\Omega &= 123^\circ.5 \\
\lambda &= 190^\circ.8
\end{aligned}
$$

APPARENT ORBIT :

Length of major axis	$= 8''.97$
Length of minor axis	$= 4\ .21$
Angle of major axis	$= 121^\circ.6$
Angle of periastron	$= 117^\circ.5$
Distance of star from center	$= 2''.23$

The element λ is reckoned in the direction of the motion in accordance with the plan adopted by Dr. See to secure uniformity in this respect. This quantity would be $169^\circ.2$ if measured in the opposite direction, as has been done in some of the published orbits.

This is one of the few binaries where the period is fairly well

* Communicated by the author.

known. The final result will probably not differ more than one year from that given here. This orbit is substantially identical with that found by Gore in 1888. Sixteen orbits of this system have been published, with periods varying from 73 to 98 years.

CHICAGO, July 6.

THE ORBIT OF $O\Sigma$ 285.*

S. W. BURNHAM.

In the SIDEREAL MESSENGER for June, 1891, I gave the apparent orbit of $O\Sigma$ 285 with a list of the measures down to that time upon which it was based. From this I deduced the period but by a clerical error it is printed in the paper referred to as 72.7 years instead of 62.7. The other elements of the real orbit were not given.

Mr. Gore has recently published a new orbit of this pair in *Monthly Notices* R. A. S., for April, 1893, which differs in every material respect from the previous orbit. It is a good example of totally dissimilar results being derived from precisely the same data. It seems to me that the measures are better represented by the first ellipse; but, however that may be, it will be of some interest now, and more hereafter, to show on the same diagram the two orbits. I have carefully gone over my original diagram, and as I see no reason for changing it in any respect, it is reproduced exactly as it was given with the addition of the position derived from my measures at Mt. Hamilton in 1892. This orbit is marked A. The ellipse B is that found by Gore, using the same observations, including the last set of measures in 1892.

For a further comparison of the two, I have obtained from my orbit all the elements:

BURNHAM.	GORE.
$P = 62.1$ years	118.57 years.
$e = 0.429$	0.58
$a = 0''.387$	$0''.46$
$T = 1885.3$	1881.93
$i = 44^\circ.3$	$45^\circ.7$
$\Omega = 54\ .3$	$106\ .58'$
$\lambda = 180\ .0$	$161\ .4$

If the second orbit is correct, this will soon be an easy pair to measure, and it is probable that the present year will show

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* Communicated by the author.

PLATE XXXII.

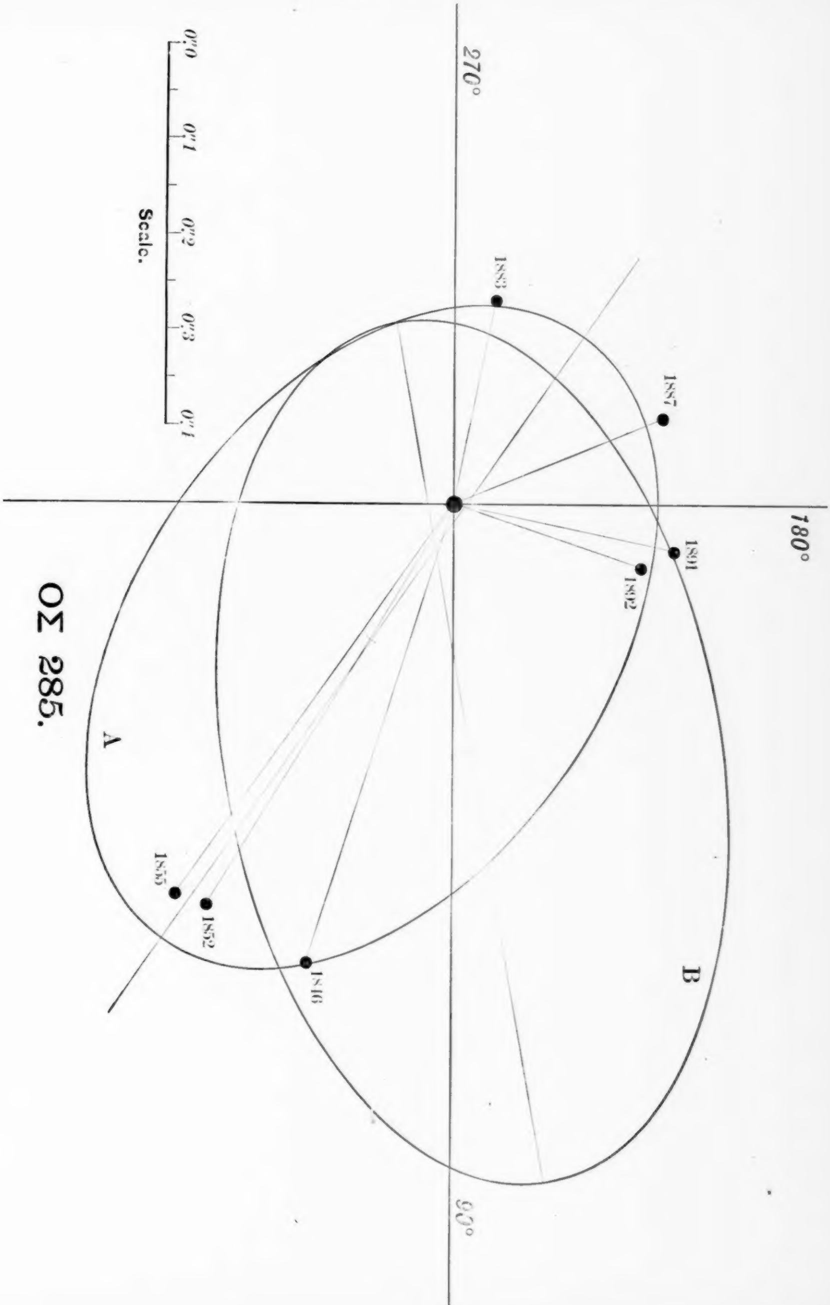
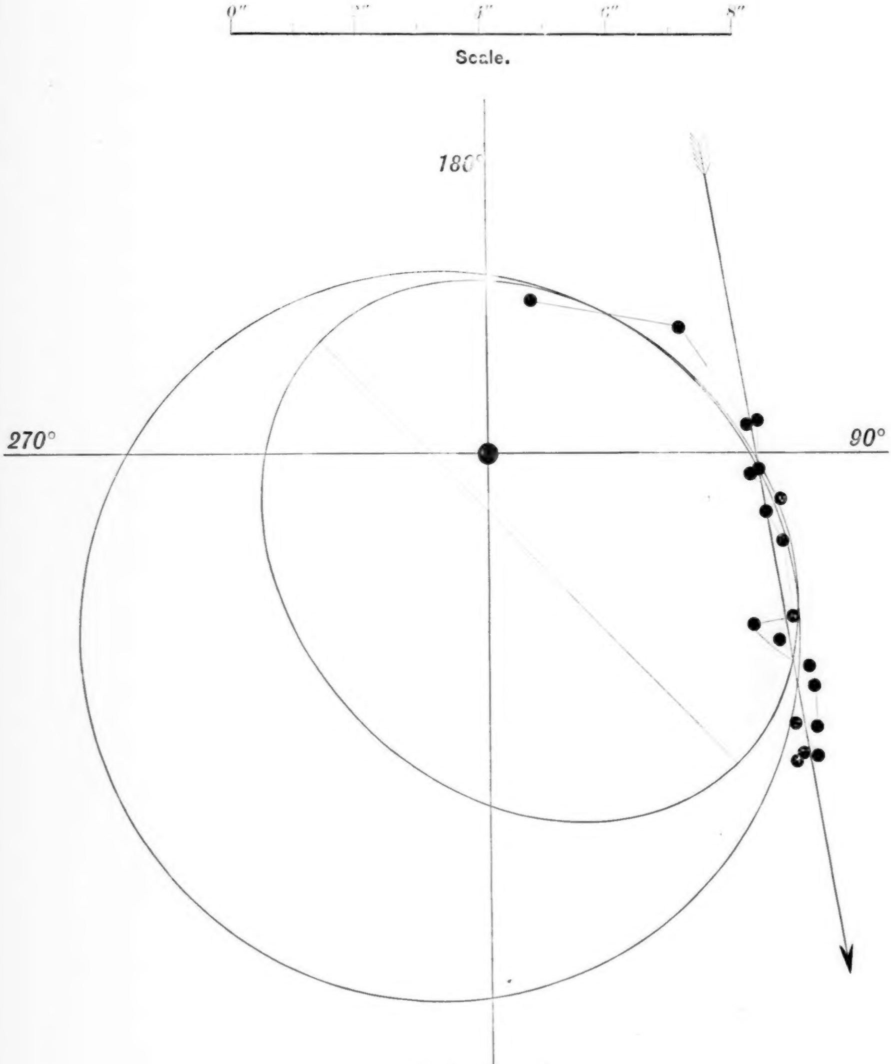


PLATE XXXIII.



6 Eridani.

whether or not the distance is really increasing. According to my ellipse the distance between the components will not exceed 0″.25 for some years to come. Of course in any event the elements at this time are only provisional, but annual observations for the next three or four years should define the general form of the apparent orbit.

I have not given a comparison of the errors of the observations according to the respective orbits, as that sufficiently appears from an inspection of the diagram.

CHICAGO, June 1.

NOTE. Since the foregoing was written, I have had an opportunity, in company with Professor Hough, of examining this pair on June 16, with the 18½-inch refractor of the Dearborn Observatory. It appeared certain from inspection that no sensible change in the distance had taken place since my measures at Mt. Hamilton in 1891 and 1892. It is a rather difficult pair with the Dearborn telescope, but I made on this occasion what seemed to be a fairly good measure; and obtained 156°.0 for the position angle, and 0″.24 for the distance. This would seem to indicate that the distance is not increasing, and that the shorter period is more likely to be correct.

THE MOTION OF 6 ERIDANI.*

S. W. BURNHAM.

This is a very wide pair, but with considerable relative motion. As the declination is nearly 57° south, it is beyond the reach of all observers in the northern hemisphere. The character of the motion has been the subject of considerable discussion. If the early measures of Dunlop and Herschel are to be relied upon, there can be no doubt of the two stars forming a binary system, but all of the later measures tend to show that the motion of the companion is rectilinear. Four computers, upon the assumption that the motion is orbital, have deduced from the measures the orbit of the system, obtaining the following periods: Doberck, 117 years; Jacob, 123 years; Downing, 224 years; and Gore, 302 years.

In the accompanying diagram I have laid down the orbit by Downing (*Monthly Notices*, March, 1883) and the measures as he has given them upon which the orbit is based. He did not use

* Communicated by the author.

the last five positions, being the measures of Pollock and Sellors, but I have inserted them as having a bearing upon the question, still undetermined, of the real character of the motion. At the time of making this diagram I had overlooked the later orbit by Gore (*Monthly Notices*, November, 1887), but in this connection it is not important, since it is apparent from an inspection of the measures down to this time, that even if the two earlier positions of Dunlop and Herschel are substantially correct, the problem of the real orbit is an indeterminate one, and an ellipse which would require a period of many hundred years, even a thousand or more, will satisfy the measures as well as any period which has been found. I have drawn a circle on the diagram, which, it will be seen, represents the observations at least as well as the ellipse. It is evident that a great number of ellipses could be readily drawn which would do the same thing; therefore, even if it be conceded that this is a physical system, it will be another hundred years at least before even an approximate orbit can be found.

With respect to the nature of the relative movement, there is very little to say beyond what appears from the actual measures. It seems improbable that Dunlop's observation can be so far wrong as to be very much inferior to an ordinary eye estimate; on the other hand all of the measures since 1845 can be well represented by rectilinear motion, and Herschel's position in 1835 will be in substantial harmony if we may assume that his distance is about 1″ too small. In fact one of his estimates with the large reflector made the distance 4½″ at this time. If the change in the companion is due to proper motion, then it must have a relative annual movement of about 0″.11 in the direction of 10°. I think the probabilities are in favor of rectilinear motion, taking everything into account, but at present it is a matter of judgment only, about which astronomers may differ widely. Annual measures for the next ten years should determine this question.

CHICAGO, June 17.

A MICROMETER FOR MEASURING THE PLATES OF THE ASTROPHOTOGRAPHIC CHART.*

W. H. M. CHRISTIE, ASTRONOMER ROYAL.

For the measurement of the catalogue plates of the Astrophotographic Chart, the micrometric slide originally made by

* *Monthly Notices* of R. A. S., March, 1893.

Messrs. Troughton & Simms for the measurement of the distance of *Venus* from the Sun's centre on the transit of *Venus* photographs, 1874, by the help of an auxiliary millimetre scale on plate-glass, has been adapted to the ready determination of rectangular coordinates and diameters of disks of stars on 16cm × 16cm plates.

MICROMETER FOR STELLAR PHOTOGRAPHS, ROYAL OBSERVATORY, GREENWICH.

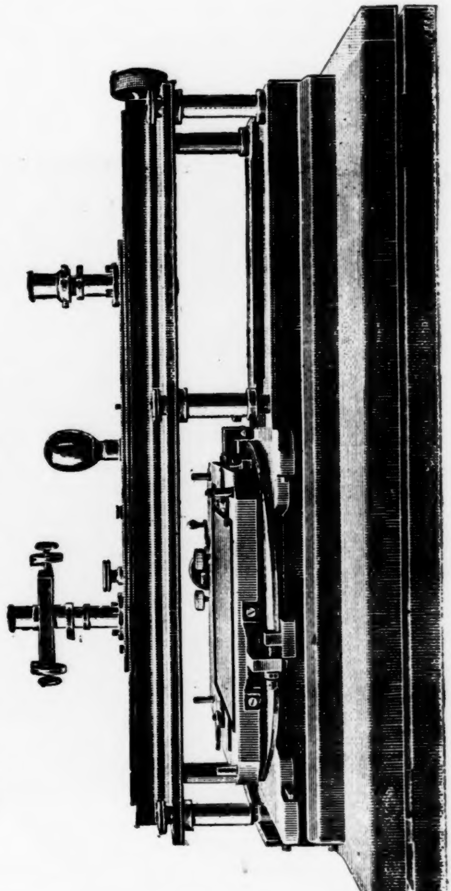


FIG. 1.—View nearly in plane of photograph.

The two figures will give an idea of the general arrangement.

Two microscopes, rigidly connected, are mounted in a longitudinal hollow frame or slide, which can be moved quickly by hand to any position in a long slide, and clamped securely. A

slow motion can be given to this latter and to the frame carrying the two microscopes by means of a screw, shown on the right. The photographic plate (in a suitable frame) is viewed by the left-hand microscope (which is provided with a parallel-wire micrometer, to be described presently), and a glass scale, divided into millimetres, is viewed by the other. The plate is held in its frame, with film uppermost, in precisely the same manner as in the plateholder at the breach end of the photo-telescope, being

MICROMETER FOR STELLAR PHOTOGRAPHS, ROYAL OBSERVATORY, GREENWICH.

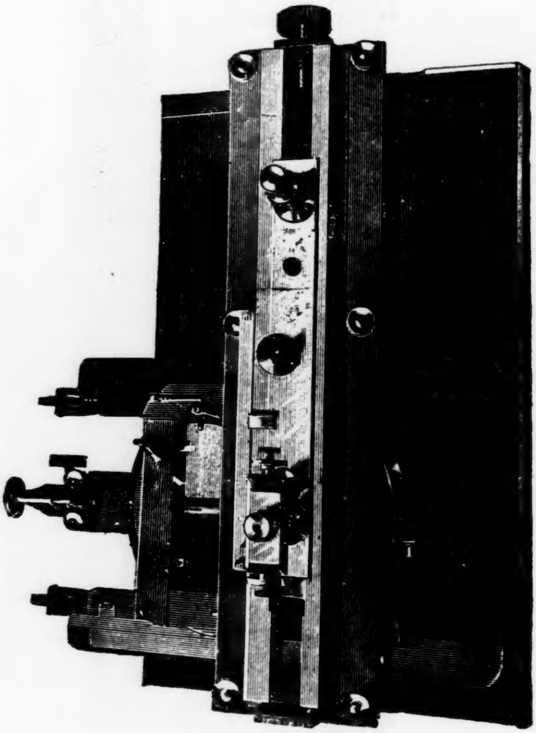


FIG. 2.—View from above.

pressed laterally by springs against two studs on one side (for orientation), and against one stud in the middle of the adjacent side (for fixity of position), the film side being kept in bearing with three studs in the focal plane of the microscope (at two corners and the middle of the side opposite) by three springs immediately below. The frame in which the plate is held is capable of rotation through 90°, banking against adjustable

screws so that the cross lines of the réseau can be successively placed parallel to the micrometer slide and coordinates measured in the two directions at right angles. It is, further, mounted in a slide perpendicular to the micrometer slide (with adjustment for accurate perpendicularity), so that by the longitudinal motion of the microscope and the transverse motion of the photograph, any point of the latter can be brought under the microscope, the approximate coordinates being read off by millimeter scales attached to the two slides. The whole instrument is mounted on a hinged wooden frame so that the plane of the photograph can be tilted to any convenient angle for vision by transmitted light from a reflector or white paper below, the plate and frame being counterpoised by two weights running over pulleys at the top of the transverse slide.

The star to be measured having been brought near the center of the field of the left-hand microscope by the quick motion, the microscope frame is clamped, and, by means of the slow motion, the corresponding division of the millimetre scale is bisected by the fixed parallel wires of the right-hand microscope. The star is then measured with the left-hand micrometer-microscope. This is arranged to give readily the reading for the center of the star's disc and its diameter, the principle being that devised by Sir G. B. Airy for the Reflex Zenith Tube at Greenwich. There are two micrometers, A carrying its own wire and also the bearing of B, which carries a parallel wire. The screws for A and B have the same pitch, representing $20''$ or $\frac{1}{3}^{\mathrm{mm}}$ on the plate, and the heads are divided (in opposite directions) into 100 parts, so that in the sum of two readings 1 div. $= 0''.1$. (It is intended that the two readings should be taken as a rule.). It will be seen that if a and b are the readings of two micrometers when their wires (crossed relatively to their respective heads) are placed on the two edges of the star's disc, its diameter would be b (the zero of micrometer B being adjusted for coincidence of its wire with that of A), and the reading for its center would be $a + \frac{1}{2}\, b$. One coordinate having thus been measured, the plate is rotated through 90°, and the other is similarly obtained, while the photographic magnitude is inferred from the measures of diameters (by microscope B).

By this arrangement it will be seen that the positions of stars can be expeditiously found without the necessity for measurement of the lines of the réseau, and thus great labor may be saved.

REV. CHARLES PRITCHARD, D. D., F. R. S.*

WILLIAM E. PLUMMER.

I regret to have to inform you of the death of the Rev. Charles Pritchard, Savilian Professor of Astronomy and Director of the Oxford University Observatory. The deceased Professor was in the 85th year of his age, and to within the last few days was able to take an active part in the conduct of the Observatory and in the duties connected with his chair.

It was not till Professor Pritchard was considerably advanced in life, that he began to take an active share in astronomical research or to give signs of that energy and zeal which characterized his later years. In 1866 he was made President of the Astronomical Society, and this seems to have been the turning point of his career, for shortly after, he was appointed Savilian Professor of Astronomy, in succession to Professor Donkin, and then began that energetic conduct of the University Observatory with which your readers are familiar. It may be as well to recall that at that date (1870) the University of Oxford possessed no Observatory and no instrumental equipment. It may not be unnecessary to remind your readers that the control of the Radcliffe Observatory and its connection with the Savilian chair of Astronomy had ceased many years previously, and from the time of the appointment of Mr. Johnson to the duties of the Radcliffe Observer, the University had remained without any adequate means of educating its students in astronomy or of conducting any series of observations. This defect Professor Pritchard set himself immediately to rectify, and found the University eager to assist him. Under these happy circumstances a small but well equipped Observatory was at once commenced, and this was fortunately enlarged by the munificent and well-timed gift of the late Dr. Warren de la Rue. This latter contribution consisted chiefly of reflectors, and since the University had ordered a refractor from Sir Howard Grubb, the Professor early found himself in possession of the necessary instrumental means to prosecute his inquiries in whatever direction he pleased. He first turned his attention to the observations of double stars and comets, but abandoned these branches of observations as they did not permit any scope to originality. Meanwhile he kept steadily in view a proposal made to him by Dr. De la Rue to determine the Moon's physical libration by means of measurements made on negatives

* From *Astronomische Nachrichten*, No. 3171.

of the Moon. The experience gained in this class of enquiry convinced Professor Pritchard of the superiority of the measurement of the photographic image over the more direct measurements made in the field of the telescope, at least, in some instances. In a climate where the observations were peculiarly liable to interruption from cloud he appreciated the possibility of effecting an observation in a few seconds whose measurement could be leisurely completed at another time. The lesson he learnt in those days with the old collodion films was destined to bear fruit later on; and his devotion to photography and his belief in its accuracy deepened as newer processes put within his reach impressions of fainter objects and more varied detail. In this spirit he was prepared to give the greatest assistance and cordial support to the scheme of the late Admiral Mouchez and the Brothers Henry. In the earliest days of that scheme, and before the slower machinery of departments of state could be made operative Professor Pritchard assisted again by his friend Dr. De la Rue, was urging on Sir Howard Grubb the necessity of providing him with a photographic object glass, of the pattern recommended by the Paris Congress; and the writer well remembers the mortification felt by the late Professor at the delay that the difficulties of manufacture interposed between the inception and the completion of the scheme. Some portion of the interval was practically and usefully filled by photometric comparisons carried out by means of a wedge of neutral tinted glass. This "wedge photometer" had been devised for the purpose of forming an Uranometria on strictly scientific lines. It had been used not only for the determination of the magnitude of the stars in Argelander's Uranometria but it had served likewise for investigating the amount of light absorbed by the atmosphere. This inquiry was conducted both in Egypt and in Oxford, and the result is in practical unanimity with the more recent inquiries. The importance of these photometrical researches was recognized by the Royal Astronomical Society, and their gold medal was awarded to him in conjunction with Professor Pickering, who had been engaged in stellar photometry about the same time.

But Professor Pritchard returned to photography with more than his old ardor. Preliminary enquiries had convinced him of the accuracy of his measurements on photographic films and he believed that he held in his hand the means of rapidly increasing our knowledge of the parallax of the fixed stars, and with this view he sought to determine the distance of the stars of the second magnitude, visible at Oxford. How he succeeded is known

to the readers of the *Astronomische Nachrichten*. He derived the parallax of some thirty stars, principally of this magnitude, and believed that he thereby made a step towards the solution of a great cosmical problem. This last work received the reward of the medal of the Royal Society, but the Professor did not think for one moment of resting on his well earned rewards. Other problems were engaging his attention and his indefatigable zeal overlooked the age at which he had arrived and in the midst of his work he succumbed, on Sunday, May 28, after only a few day's illness.

THE DEVELOPMENT OF THE SOLAR SYSTEM.*

DANIEL KIRKWOOD.

Were all members of our planetary system originally solid?

A consideration of facts apparently bearing upon this question led the present writer a few years since to a negative conclusion. If either nebulous or gaseous, or if from any cause readily disintegrated, the dismemberment of the external parts would be a question of circumstances. Assuming the system of Mars and his satellites to have originated as in the cosmogony of Laplace the mean density of the primary when filling the orbit of Phobos was about $\frac{1}{21}$, the present mean density of Mars being unity. The tendency to the centre of Mars was 0.107. The weight of one pound on the surface of Phobos was $\frac{1}{360000}$th of one pound, the radius of the satellite being the same as the present. In other words, the tendency of a disconnected mass or particle at the surface of Phobos would be greater *toward the primary* than to its own centre. If, therefore, free to move, the process of ring formation, as in the case of Saturn's annuli, was in operation at an epoch indefinitely remote. The origin of Saturn's rings may thus be explained. A similar process may also be applied, as has been shown by Pickering,* to the satellites of Jupiter, especially to Barnard's.

The ancient history of the solar system—the origin of comets and of meteoric streams—the question whether cosmical rings precede or follow planetary formations—the zodiacal light, its origin and explanation, all afford questions for future discussion, and promise results of no ordinary interest.

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* Communicated by the author.

† ASTRONOMY AND ASTRO-PHYSICS, June, 1893, p. 486. See also "The Formation of Rings as a Process of Disintegration," by Dr. M. W. Meyer, ASTRONOMY AND ASTRO-PHYSICS, May, 1893, p. 410.—"Analysis seems to indicate *that planets and comets have not been formed from rings, but rings from planets and comets.*" SIDEREAL MESSENGER, April, 1885, p. 72.

ASTRONOMY IN RUSSIA.*

S. W. BURNHAM.

We are sorry to learn that astronomical work at the Observatory at Abastuman, Tiflis, in the mountains of south-eastern Russia, has been permanently discontinued, and Professor Glasenapp has returned tothe Observatory of the Imperial University at St. Petersburg. Professor Glasenapp who is well known as one of the leading astronomers in Russia, and one of the most energetic and expert observers with the micrometer to be found anywhere, has done a large amount of most valuable work in several fields, and particularly in the measurment of double stars. It was not only thoroughly done, but promptly published, and made available at once to other astronomers working in the same fields His observations show conclusively, not only from the amount of work done, but the character of the stars measured with a small equatorial, that the site of Tiflis was remarkably favorable for astronomical work. If one may judge by results, and certainly there is no better way, no Observatory in Europe has so favorable a location, and it would be difficult to name one elsewhere, aside from that at Mt. Hamilton, where the atmospheric conditions are equally favorable. The advantages to be gained by placing telescopes on moderately high mountain eleva tions have been so thoroughly demonstrated that this is no longer a debatable question. The gain thus secured in the greater purity, steadiness and transparency of the air, to say nothing of the increased number of clear nights, is a very important factor in the results obtained, and will be best appreciated by those who have had an opportunity to observe under such conditions.

For more than half a century Russia stood at the head of all the world in the discovery and measurement of double stars. The two Struves secured immortality by their great work in this important field, and the fame of the Dorpat and Pulkowa Observatories rests upon the same secure foundation. Of late years very little has been done, or published, at the last named Observatory, and the great 30-inch equatorial, the second largest telescope in the world, seems to have been devoted to other than micrometrical work so far as one can tell from official and other publications. Professor Glasenapp, with optical means vastly inferior to anything used by his illustrious predecessors, has under-

* Communicated by the author.

taken to place his country again pre-eminent in this field. He has already accomplished much, and with an instrument even as large as the old Pulkowa refractor, it is certain he would secure brilliant results. Unfortunately the telescope of the Imperial Observatory is a small one, but doubtless the Russian government will place him in a position to carry on with more powerful instruments the work inaugurated at Abastuman.

COMET *b* 1893.*

W. W. PAYNE.

This new comet was almost simultaneously discovered at two places, Alta, Iowa, and Salt Lake City, Utah. Telegraphic announcements also from the two places reached us almost simultaneously. The discoverer at Salt Lake City was Mr. Alfred Rordame and the time reported was July 8, at 10 o'clock P. M., supposably Mountain time. The message was sent to Dr. Lewis Swift of Rochester, thence to Harvard College Observatory and then, in cipher, to Goodsell Observatory, being received at the last place at 7 o'clock and 20 minutes Monday morning, July 10. At Alta, Iowa, July 8 at 9 o'clock 30 minutes, Central time, Charles Johnson and James Miller saw the comet with the naked eye and reported it to David E. Hadden, a well-known amateur observer of that place, who is regularly watching the northern skies for auroræ on Dr. M. A. Veeder's plan. On Sunday evening Mr. Hadden observed the comet and telegraphed to Goodsell Observatory the same night, asking what comet it was. The telegram was not received until Monday morning at 8 o'clock and 35 minutes. The messages were both behind time, and afford another common example of the kind of telegraph service the public has to endure. Mr. Hadden's letter written on the 10th was received Tuesday morning. From that letter we take the following paragraph:

"It was first observed here about 9 o'clock Saturday night, July 8, visible to the naked eye, but no telescopic observations were obtained until last evening (Sunday) when the comet had increased much in size. It has a bright large nucleus with much nebulosity surrounding, and for about 5° the tail is narrow and straight. Its full length could be traced for a distance of about 15° in a N. N. E. direction. There are indications that a faint

* Communicated by the author.

small companion tail extends for a short distance on one side of the "head." Its approximate position for July 9, is, right ascension $8^h\ 5^m$, Decl. 49° north. It appears to be moving very rapidly."

As far as appears from telegrams and letters pertaining to the discovery of the new comet so far received, the observers at Alta, Iowa, saw it about one hour and a half earlier than others, though the claim of Mr. Rordame of Salt Lake has been usually admitted heretofore. His certainly is an independent discovery. Another letter received from Mr. Hadden under date of July 14, adds a fact of some interest. He says:

"About 9:30 P. M. on the previous night, July 7, I examined the northern sky as usual for auroras, in coöperation with Dr. M. A. Veeder's plan, and noticed this object in the constellation of the Lynx, but it appeared merely as a large diffused or hazy star with no tail visible to the naked eye; hence, I did not suspect the nature of the object, and made no telescopic observation; the following evening (Saturday) the comet with the bright short tail was easily picked up by Messrs. Charles Johnson and James Miller."

From these statements it seems probable that the comet was an inconspicuous object preceding the 7th of July, that it was easily visible to the naked eye on the 8th, on the 9th increasingly bright in regard both to nucleus and tail, and that on the 10th and 11th it was at its best so far as observations at the present time show.

On account of clouds the comet was not seen at Goodsell Observatory on Monday (10th), but was observed well on Tuesday night. The position obtained on July 11.720 by the aid of the 16.2-inch refractor was as follows: right ascension $9^h\ 09^m$, declination + 44° 49′.

This position was taken by Dr. H. C. Wilson and Professor Leavenworth of the State University who is spending a few weeks at the Observatory for the opportunity of doing some astronomical work in the line of measuring difficult binary stars.

On the same evening also, at 10 o'clock P. M. Central time, Dr. Wilson obtained two photographs of the comet, by the aid of the 8¼-inch photographic telescope and an ordinary camera attached to the tube of the telescope. The exposures were simultaneous, the former lasting for 35 minutes and the latter 45 minutes. The frontispiece to this number is the camera picture enlarged about 2½ diameters. It is a photogravure reproduction and fairly well presents the detail of the original plate. The two prominent star trails in line with the nucleus and about five degrees distant are ι

and κ Ursæ Majoris. On the same side of the tail and near the edge of the plate will be seen two other trails fully as bright and nearer together; these are θ Ursæ Majoris. A large number of other stars may be identified by the aid of a good star map. The length of the tail as shown on the original negative was fully 12°. A greater length could probably have been photographed if the field of the camera had been larger, or if the coma had been placed outside of the center, so that the field would have covered more of the tail. By the naked eye the train could be traced, at the same time, fully 18°, fading from view in the region of small stars near β Ursæ Majoris.

The structure of the tail is shown in the plate much better than it was seen in the telescope at that time. Three streamers are noticed about the head. One on each side of the train, extending several degrees backward from the head and making a small angle, with the tail are the most prominent ones. The prolongation of the nebulosity towards a near star at right angles with the tail was a feature noticed also in the telescope. On the original plate the divisions of the tail extending from the region of the coma to its extremity can be easily followed. These markings could not be seen in the telescope, and were not known here until seen on the photographic plate. Only one streamer was observed visually and that was so faint as to be uncertain to all observers. The elongation of the nebulosity at right angles to the train was also suspected visually by two observers.

A number of other good photographs of the comet were taken on subsequent evenings, a description of which is given elsewhere in this number.

The nucleus of the comet was measured by Professor Leavenworth, on the evening of the 11th and was found to be 8″ of arc in diameter, while the micrometric measure of the coma was 78″. The coma was about the brightness of a second magnitude star. There was no detail to be observed in either, worthy of mention, beyond that which has already been given.

On the morning of July 13, a telegram was received from Harvard College Observatory containing the elements and the ephemeris of the comet computed by Professor Lewis Boss of Dudley Observatory, Albany, N. Y. These elements were known to be only roughly approximate, having only one day intervals between the observations from which they were derived. It was noticed at Goodsell Observatory on the 13th and after that date that the errors of the ephemeris both in declination and right ascension were so great as to indicate considerable error, either in

the places used by the computer or in finding his results from them. In view of this a parabolic orbit with observations of two day intervals was computed at the Goodsell Observatory by Professor Leavenworth and Dr. Wilson and the result obtained will be found under Comet Notes in this issue.

The fine auroral display witnessed on the evening of the 15th with its wonderful curtained bands reaching nearly to both horizons, east and west, was in no way connected with the comet, although some observers seemed to think so from current newspaper reports. Its spectrum showed a single bright line, presumably the usual auroral line so called.

We have not yet been able to verify the reported discovery of a small comet within the train of Comet *b*, recently found on the photographic plates taken at the Lick Observatory.

GOODSELL OBSERVATORY,
July 19, 1893.

THE ZODIACAL LIGHT.

Arthur Searle of Harvard College Observatory, has recently published in the Annals of that institution, Vol. XIX, Part II, a paper entitled, *Researches on the Zodiacal Light*. It is a discussion of the results obtained at Harvard College Observatory by previous observers and by himself on that subject. "A large part of the treatise relates to the phenomenon of Gegenschein or Counterglow, the observations of which at other places, as far as they have come to the notice of the author, are here collected and compared with each other, and with those made at that Observatory." The period of time covered by the observations reported is from 1840 to 1890. Those from 1874 that were recorded at Harvard were principally made by the author of this paper. But he is careful to say in the outset that the Zodiacal Light has never been regarded at the Harvard Observatory as a prominent subject of investigation, and that the information relating to it which is derived from the Observatory records comprises such facts as could be collected, at irregular times, during the intervals of more systematic work. Notwithstanding this imperfection and haste of the observations, it is apparent that they exhibit facts which may be serviceable in leading to better and more correct opinions in regard to the Zodiacal Light.

The first query raised is, whether or not the Zodiacal Light is a phenomenon that is constant or variable in brightness if impedi-

ments to observation are not considered. The answer to this query is drawn from the experience of fourteen seasons of observations at the Harvard Observatory which shows that the phenomenon has been nearly, if not absolutely permanent, "and seldom subject to any large variations." These seeming variations can not be certainly established, owing to the defects of observations already referred to, as well as others that might be easily named. Observers have noticed, or spoken of, three phases of variation; 1, Variation in light from minute to minute, 2, Variation from day to day, and, 3, Variation from year to year. The author's decisive test for the first phase of apparent variation is the simultaneous observations by different observers not acquainted with each others conclusions. In the case of slight variations due to atmospheric changes, it is suggested, that, perhaps, sufficient photometric observations of stars in different parts of the sky, accompanying the observations of the Zodiacal Light, might remove this difficulty.

The variation of the Zodiacal Light from day to day, appears to be true from a few observations, but the author still thinks that these observations may possibly be misleading, and states reasons why or how they may be so, and they certainly seem reasonable in the absence of crucial tests, similar to those named for the preceding phase, as this second one is much like the first in kind, if the average brightness of the Zodiacal Light for one evening be compared with that of another.

The third phase of supposed variation from year to year, one might expect would be less conclusive, from observation than either of the preceding ones, yet the author cautiously says: "If we may venture to draw any inference from the record of observations as a whole, it may be said slightly to favor the hypothesis of a variation in the Zodiacal Light coincident with the variation of the quantity of solar spots, and of auroral displays, but the support thus obtained for that hypothesis is certainly very feeble." The evidence, then, is undecisive in regard to the variation of the Zodiacal Light in either of these three ways.

Interesting associated facts do appear that may be named in this connection. For example, the ordinary brightness of the central parts of the Zodiacal Light has been estimated by previous observers to equal, or exceed, that of the Milky Way, at the same altitude, and these estimates are confirmed by a few of the Harvard observations in 1881 and 1883.

It is also noticed that the Zodiacal Light becomes fainter as the evening advances, but it can be traced to greater distances from

the Sun. The form and position of this phenomenon has always claimed attention. Observers in different latitudes vary somewhat in regard to the position of its axis. Some have said that the apparent position varies with the inclination of the ecliptic to the horizon, moving towards the upper side of the ecliptic as the altitude of the ecliptic diminishes. This effect might possibly be due to atmospheric absorption, that could not be certainly decided without further evidence.

Another feature of interest is the brighter interior and the fainter exterior portions of the Zodiacal Light. This stronger interior light is not of uniform brightness, nor is it as bright near the vertex as it is in the brighter portions of the diffuse light at a smaller altitude. If the eye is swept across the axis from north to south, it is noticeable that, at a point considerably within the extreme boundaries of the light, there is a rapid decrease of brightness indicating a secondary boundary between an inner and an outer cone. This is a delicate observation, but it is also one of very unusual interest for some observers.

Another class of phenomena associated with the Zodiacal Light may now be noticed in order. We refer to the so-called "Gegenschein" as designated by Brorsen, which means a slight glow of light about 180° from the Sun, and also the belts or bands of light which have been observed in the sky, especially those in the Zodiac supposed to have some relation to the Zodiacal Light. Better observations of these phenomena have been made than of the ordinary Zodiacal Light. The apparent extension of this phenomenon, in the months of November and December, as far as the Pleiades, as a narrow band of light, was first examined at Harvard Observatory in 1875. This had been noticed by previous observers. But whether or not the band thus observed is a part of the Zodiacal Light seems questionable, because portions of the same band are so situated that its origin, as some think, may belong to another locality. The real nature of these Zodiacal belts, and their true relations are themes worthy of careful study.

There seems to be no doubt of the existence of the "Gegenschein" or the "Counterglow," as it is sometimes called, for observations of it have been too frequent and too general; but that these observations are sufficient to determine its nature is yet very doubtful. After the consideration of various hypotheses in regard to the origin of the Zodiacal Light, that which ascribes it to reflection from small meteoric bodies, or even meteoric dust, seems more probable than that of any other. This hypothesis is by no means regarded as strongly probable from known proofs,

because the most natural suppositions that have been made for the distribution of meteoric dust in the region of the Zodiac have not been verified by the results found in the use of analytic methods, involving equations that are simple enough in themselves, but whose predictions fail to be certainly verified by observation. For example, if this meteoric matter be assumed to be distributed not evenly in the Zodiacal belt, but rather diminishing in density with increasing distance from the Sun, and more rapidly so than has hitherto been supposed, but that this decrease is checked after a time, and that a considerable quantity of this finely divided matter accompanies the visible asteroids around the Sun, we have as satisfactory a conjecture as any known; but the results of theory are not verified in the "Gegenschein" and the bands and the variations in the Zodiacal Light by observation, as fully as is desired for a satisfactory scientific result.

It would be profitable for any one to follow the discussion of this paper more closely, to notice the tabular evidence it furnishes and the details of statement presented, as well as the more gen- eneral conditions which herein have been too briefly stated to do it justice.

SYSTEMATIC STUDY OF AURORAE.*

W. W. PAYNE.

It is with marked interest that we have noticed the recent developments of a scheme for a thorough, comprehensive and a more systematic study of the phenomena of the Aurora. Heretofore, generally, the observations of these and other related phenomena have been made in a desultory way, as the interest of individual observers would prompt them to do, when displays were either obtrusive, or easily seen by the watchers of the nightly skies. The observing-books of astronomers, the weather records, the casual studies of physicists, and other similar sources, furnished the greater part of the data for the work of the meteorologist, in this part of his science, and, apparently he has made the most he could of this kind of raw material, in trying to determine the nature of the aurora and the laws which govern its manifestation. Much theory and speculation concerning the meaning of the aurora have been advanced by scientists, in all time past, but the real data to support the theories have been sadly wanting, so

* Communicated by the author.

that no large generalizations could be made that would gain the assent of scholars, and consequently there has been very little gain in knowledge concerning it during the last half century.

For some time past, as the readers of this journal know, Dr. M. A. Veeder, of Lyons, N. Y., has been himself giving large attention to the study of the Aurora. He has formed a plan and put it into execution, by which a large number of observers in the United States might coöperate systematically in observing auroral displays. Not satisfied with the limited area of the United States, Dr. Veeder has more recently sought to extend his system to all available parts of the world, and it must be encouraging and gratifying to him to realize the success already gained in this wider field. Some account of this was given in a recent issue of the New York *Sun*, as follows:

"The fact that scientific men regard it as desirable to make these world-wide observations, so that simultaneous records from all parts of the world may be compared, is shown by the hearty endorsement and co-operation they are giving to Dr. Veeder's project. In the far north Mr. R. E. Peary, who is about to sail for Murchison Sound, Greenland, where he will erect his camp in 77 degrees 30 minutes north latitude, will give particular attention to recording his observations of auroral phenomena. On his way north he will also arrange for observation at Godthaab and Godthavn in South Greenland. Mr. George Comer, an officer of the bark Canton, now on a whaling voyage, will record observations in the immediate neighborhood of the magnetic pole itself, near the northern part of Hudson's Bay. It is expected that Father Tosi, a missionary priest in Alaska, will interest himself in securing observations in that region where auroras are more numerous than at any other point in the world. Other records of interest will be collected in Iceland, Scandianvia, Finland, Siberia, Tasmania and New Zealand."

It is true that during the international polar expeditions of 1882 and 1883 many observations of the aurora were recorded in high latitudes, but no special provision seems to have been made for comparison with those made simultaneously in lower latitudes. It is now proposed to remedy this defect. Many observers are being secured on the continents of America and Europe, and ocean observations are being provided for by the distribution of blanks and instructions through the hydrographic offices of the United States and the Deutsche Seewarte. Mr. Robert H. Scott, Secretary of the Meteorological Service of Great Britian and Ireland, has presented the matter of coöperation to the Kew

Committee of the Royal Society who have specially magnetic and meteorological research in charge. The United States Ministers at Stockholm and St. Petersburg have brought the matter to the attention of the proper authorities in those countries. Assurances of active sympathy and support have been received from many observatories, particularly those devoted to magnetic work and to observations of the Sun. Especially satisfactory in this regard is the correspondence which has been had with such institutions as the Naval Observatory, Washington; the Toronto Magnetic Observatory, and Harvard College Observatory on this side of the Atlantic; and Pulkowa Observatory, Russia; Meudon Observatory, France; Kiel Magnetic Observatory, Germany, and many others. Scientific associations also are furthering the proposed researches in one way or another, as, for instance, the "Astronomical and Physical Society of Toronto," the "Astronomical Society of Michigan," the "Rochester Academy of Science" of Rochester, N. Y., and others. It is a curious and suggestive fact that members of the engineering profession appear to be as much, if not more, interested than any other class. Physicists in several universities also are in touch with the progress of the research, and arrangements have been made so that it will be possible to submit questions that may arise that will be suitable for experimentation to experts equipped with the best possible laboratory facilities. There are a multitude of questions in respect of the sources and method of propagation of auroral luminosity that may come in the course of collecting observations that will afford opportunity for exceedingly interesting experiments. The relations between auroral phenomena and meteorology, which will appear more fully in the course of this article, are such that there is certain to be increasing interest on the part of all who are interested in weather matters.

The method of observation which it is proposed to employ is very simple and requires but little time. Each observer coöperating will indicate on the blanks supplied for the purpose the absence of the aurora. Whenever this fact has been verified by observation he will enter the figures denoting the exact time at which the observation was made in the proper space in the blank. On the other hand the presence of the aurora will be indicated by writing the word "aurora" and recording the descriptive matter on the part of the sheet left vacant for that purpose.

The facts which it is especially desired to learn are the exact times of sudden changes in the brightness of the aurora, the extent of sky which it covers, and its position relative to the true north. In case observations are not made the spaces are simply

to be left blank. Each blank sheet prepared in this way covers an entire month, and is conveniently arranged so as to enable comparisons to be made at a glance between the records from different stations.

This scheme of observation has been in operation for years under the direction of Dr. Veeder. It is found that when the times are accurately given in the manner described, and the absence as well as the presence of aurora are noted, very interesting facts in regard to local distribution and the source of auroral luminosity are brought to light. It is possible in this way, also, to secure perfectly reliable information in regard to the various forms of periodicity which the aurora exhibits, some of which bid fair to be of the utmost importance in various ways. Of these perhaps the most interesting are the diurnal recurrences of the phenomena which exhibit a definite relation to certain hours of local time, even in the Arctic region, where observation is possible in winter without interruption throughout the entire twenty-four hours. It is also found that these auroral phenomena are particularly noticeable at intervals of twenty-seven and one-quarter days, corresponding in time to the synodic revolution of the sun, or, in other words, a revolution of the Sun on its axis as viewed from the earth, which is advancing in its orbit in the same direction in which the sun is revolving on its axis, thus lengthening somewhat the sun's apparent rotation period. Here are some of the facts and inferences already obtained by this method of research which justify its proposed continuance and enlargement.

Terrestrial magnetism has thus far been but little understood, but what is already known in regard to the local distribution of the Aurora and the periodicities which it manifests, intimately associated as they are with like peculiarities in the behavior of terrestrial magnetic phenomena in general, justify the expectation that it will shortly become possible to give a simple and complete explanation of the arrangement of the entire magnetic system of the globe and of the changes which it undergoes. Not only the well-known eleven-year cycle, but also the secular changes requiring centnries for their completion, and likewise the fitful and apparently irregular variations known as magnetic storms, promise to become explicable in a manner entirely consistent throughout.

. . . .

The interest at present manifested in connection with the proposed observations is very encouraging, and it is really gratifying to learn that there are so many who are willing to make some sacrifices for the purpose of advancing a research of this kind whose

only recompense may be a feeling of satisfaction that knowledge is being increased. Those who may wish to coöperate may secure all information desired from Dr. Veeder of Lyons, N. Y., in whose hands the arrangement of details has been left. Mr. Peary's expedition will record observations whenever possible during the next two years. It is desirable, however, that the observations in lower latitudes be continued as far as possible throughout the year. In any event, the results of Mr. Peary's expedition with the associated system of auroral observation will be watched with lively interest by many who appreciate the magnitude of the interests involved."

Since the above was written we learn from Dr. Veeder that arrangements for coöperation throughout the Russian empire have been completed, and that observations have been provided for at the observatories of Archangel, Pawlosk, Ekatrainbourg, on the Ural mountains, and at Irkutsk in Siberia and at other points. Application has been made by the director of the Solar Section of the British Astronomical Society for necessary information and facilities to coöperate. Similar requests are being made by individuals and institutions in Europe and America. For example, the Rev. Francis Barmien stationed at Kozyrevski, on the Yukon river, Alaska, takes a deep interest in this movement and will devote much of his spare time to observation.

The Director General of the Italian Meteorological Service has expressed his approval of the purposes of the research and promises to aid it in every way possible.

The Danish government has given instructions that at all meteorological stations in Greenland and Iceland observations be made of the aurora borealis to be compared with those made in connection with the Peary expedition.

Professor W. H. Preece, the well-known English electrician, connected with the government telegraphic service of Great Britian, will co-operate by causing records to be made of all earth currents on English telegraph lines in a manner suitable for comparison with the records of the aurora that are being secured.

The New York hydrographic office has called for a further supply of blanks for recording observations of the aurora, those previously sent having been exhausted, having been issued to ocean steamers.

Professor Carpmael of the Canadian meteorological service has supplied the names of a large number of observers very favorably situated throughout the Dominion of Canada who will take observations of the aurora under most favorable conditions in the very midst of what is known as the auroral belt.

It seems now evident that astronomers and mathematicians will also heartily join in the study of the aurora. Solar photography could do much in giving exact data pertaining to the condition of the solar surface for comparison with terrestrial phenomena. The mathematician will find expression for the forces that produce regularly recurring effects, and the mechanician will devise the new instruments needed to furnish new data for verification in cases where existing ones are ill-adapted or insufficient to do the work.

LONGITUDE OPERATIONS AT GREENWICH AND PHOTOGRAPHIC WORK.*

Immediately after visitation day last year, operations were commenced for the re-determination of the longitude of Paris. Four observers, two French and two English, took part in the work as in 1888; three of them were the same as before (Colonel Bassot, Commandant Defforges, and Mr. Turner), but Mr. Hollis replaced Mr. Lewis, whose special attention was required in the Time department. The plan of operations adopted in 1888 was only modified in the following particulars: two clocks were used instead of one, at each end of the line, and all the clocks were placed in rooms kept at nearly constant temperature. The Sidereal Standard was used by the English observer at Greenwich throughout. The English observers used the small chronographs procured for the Montreal longitude, with one pen only, thus avoiding the troublesome correction for parallax of pens.

In the first part of the operations, Commandant Defforges and Mr. Turner were at Greenwich, Colonel Bassot and Mr. Hollis at Paris. Signals were exchanged on 7 nights, on 4 of which clock error was determined at Greenwich and on 6 at Paris.

In the second and third parts the observers were interchanged; signals were exchanged on 11 nights, observations of stars for clock error being obtained on 8 of these, both at Greenwich and at Paris.

In the fourth part, the observers returned to their original stations. Signals were exchanged on 11 nights, clock errors being determined on 5 nights at Greenwich and on 9 nights at Paris.

The preliminary discussion of the English results for the difference of longitude between the Greenwich transit circle and Cassini's meridian is now complete, the mean of 25 practically independent determinations, after correcting for personal equation, being $9^{m}\ 20^{s}.82$. The value found in 1888 by English observers was $9^{m}\ 20^{s}.85$.

In July Professor McLeod came to Greenwich to discuss the first stage of the operations for the longitudes Montreal—Canso—Waterville—Greenwich. It appeared that the cable signals were for practical purposes as accurate as those over the land lines; and thus the chief difficulties of the work are, as in other cases, simply those of absolute time determination.

The second stage of the operations was commenced on August 16, and completed on September 16. It consisted of two parts, in the first of which the observers at Montreal, Canso, Waterville and Greenwich were Mr. Turner, Mr. Klotz, Mr. Hollis, and Professor McLeod respectively; signals being exchanged on every night (except in one or two cases of accidental interruption) from August 16 to August 30, and clock errors being obtained at the several stations on 8, 6, 6 and 11 nights respectively.

* Extracts from the Report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich. Read June 3, 1893.

The observers were then interchanged to the following order:—Mr. Klotz, Mr. Turner, Professor McLeod, Mr. Hollis. Signals were exchanged each night from September 3 to September 16, and clock errors were obtained on 6, 12, 6, and 10 nights respectively.

The total number of nights on which there was complete connection by signal between Greenwich and Montreal was 20.

The sidereal observations made by the Greenwich observers, and the signals, are completely reduced; but we have not yet received from Montreal the results of the time determinations by Professor McLeod and Mr. Klotz.

In the year ending 1893 May 10, photographs of the Sun have been taken with this instrument on 180 days, and of these 410 have been selected for preservation, besides 22 photographs with double images of the Sun for determination of zero of position.

The photographic telescope presented by Sir Henry Thompson, which has been mounted on the Lassell equatorial, has been in regular use as a photoheliograph since January, 1893, and photographs of the Sun have been obtained with it on 89 days, of which 158 have been selected for preservation. In all with one photoheliograph or the other a record of the state of the solar surface has been secured on 220 days during the year. A new enlarging lens by Messrs. Ross & Co., which appears to be very free from distortion, was fitted to the Thompson photoheliograph on December 13, and has been used regularly since for the eight-inch photographs of the Sun.

For the year 1892 Greenwich photographs have been selected for measurement on 197 days, and photographs from India and Mauritius (filling up the gaps in the series) on 165 days, making a total of 362 days out of 366 on which photographs are available.

The solar activity has been fully maintained throughout the past year, though no single spot has appeared equal to that of 1892 February. The mean daily spotted area for 1890 was 100, for 1891, 566, and for 1892, about 1230.

This great development of activity seriously increases the work of the department; as an example it may be mentioned that 35 books of the form used in reducing the spot positions were required for the years 1891 and 1892, while in the whole 17 years preceding, for which photographs have been measured, only 85 books had been used, 39 of these having been used in the *three* years 1882-4 of the last maximum. Notwithstanding this increase in the work, the measures and reductions are in a more forward state than at the date of the last Report. The measures of positions and areas for 1891 are now passing through the press, and the Spot Ledgers for that year are prepared for press. The photographs have been measured and reduced up to 1993 January 13, the reductions examined up to 1892 October 27, and the copy for press written up to 1892 September 10. But to cope with this unexpectedly severe Sun spot maximum it has been necessary to largely increase the number of computers employed on this work, and a further addition will probably be required if, as seems likely, the solar activity continues to increase.

Astro-Physics.

ON THE BRIGHT BANDS IN THE PRESENT SPECRUM OF NOVA AURIGÆ*

WILLIAM HUGGINS AND MRS. HUGGINS.

Some few prefatory words are called for in explanation of the partial incompleteness of the present communication.

A considerable brightening, from below the 14th magnitude to above the 10th magnitude, was found to have taken place in the Nova when it was re-observed in the early part of August, 1892, and to be accompanied by a modification of its spectrum, apparently analogous to a similar change in the spectrum of Nova Cygni in 1877, since the observations we made of the star on March 24, 1892, when it had fallen to nearly the 11th magnitude.†

In consequence, however, of the removal of the eye-end of the telescope to the workshops of Messrs. Troughton and Simms for the attachment to it of the mounting for a fine Rowland grating by Mr. Brashear, we were without the means of observing the star and its spectrum during the whole of the autumn and the early winter. It was not until the beginning of the year that the new spectroscope was mounted in our Observatory, and then, from some instrumental causes of delay and from a prevalence of bad weather, we were not able to observe the spectrum of the Nova until the night of February 1.

Before this time the altered appearance of the spectrum of the Nova had been observed at several observatories, and its spectrum had been described as consisting mainly, in the visible region, of a bright line in the orange, of the two nebular lines,and of the hydrogen line at F.

As soon as we directed the spectroscope to the star, we saw at once, even with one prism, that the two principal bright bands which had been described as the "nebular lines" were in strong contrast with these, not single lines but broad bright spaces, diffused at the ends and irregularly bright, which we suspected to be groups of bright lines.

On February 8 we observed these bright spaces with the 4-inch grating of 14.438 lines to the inch, using the spectrum of the second order. The collimator and the telescope have each an

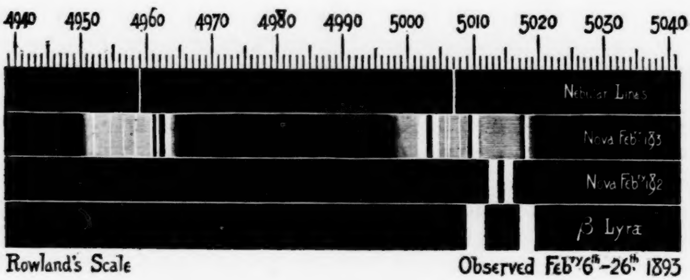
* Read before the Royal Society. Communicated by the authors.
† *Roy. Soc. Proc.*, Vol. 51, p. 492.

aperture of 2 inches, and the spectrum was viewed under a magnifying power of 23 diameters. Our suspicion was then confirmed, the bands being clearly resolved into groups of bright lines upon a feebly luminous background.

On February 26, micrometric measures were begun of the positions of the constituent lines of the groups, when unfortunately we discovered that in consequence of flexure in one part of the instrument, a shifting of the micrometer webs relatively to the lines of the spectrum was liable to take place, and so make the measures uncertain to about as much as 2 tenth-metres when the spectrum of the second order was in use.

The cause of the want of rigidity of the instrument in this respect made it necessary that the spectroscope should go back to Messrs. Troughton and Simms' workshops; and then, from unavoidable delays and the coming in of the Easter holidays, it was not until the second week in April that the spectroscope was again in position for use; but by this time the Nova was too far past the meridian for satisfactory observations to be made upon its spectrum.

Our opportunities of working upon the spectrum of the star were thus absolutely restricted to the few fine nights between February 1 and February 26; and further our observations of the positions of the lines are, for the reason we have mentioned, affected with a possibility of error which may be as great as 2 tenth-metres, though it is probable that the positions given in the diagram are not actually in error to as much as half that amount.



For the same reason the resolution of the minor features of the groups has not been worked out with the completeness which was well within our instrumental means, if the number of fine nights had not been so limited, for on some of the nights on which

observations were attempted the sky was not clear enough from thin haze for the resolution of the more difficult features of the spectrum of a star of between the 9th and 10th magnitude.

Still, notwithstanding the comparatively incomplete state of our observations, which we greatly regret, we do not hesitate to consider them of sufficient importance, bearing as they do upon so remarkable a phenomenon as would be the change of a star into a nebula, to justify us in communicating them to the Royal Society.

The spectroscope is provided with a 4-inch Rowland grating by Brashear, and a prism of dense flint of 27°, silvered on one face, which can take the place of the grating in the grating box.

As we have already stated, the observation of the Nova with this prism showed the bright "lines" broad and irregularly bright, and raised the suspicion in our minds that they were probably groups. They were observed more or less successfully with the grating, usually with an eye-piece magnifying 23 diameters, on February 8, 10, 11, 16, 17 and 26.

1. *Brighter Group near the Position of the Principal Nebular Line.*

The separate results of our more favourable observations of this group on the different nights are put together in the accompanying diagram. In addition, however, to the details drawn in the diagram, at several very favourable moments of seeing, we had distinct and undoubted glimpses of finer lines in the spaces between the brighter ones, of which some only are given in the diagram. For this reason the diagram must be regarded as an incomplete representation of the group, though showing accurately its main features and general character.

The group, as shown in the diagram, extends through a little more than 15 tenth-metres, and consists of lines more or less bright upon a feebly luminous background, which can be traced to some distance beyond the lines at both ends of the group. The more prominent features are: two lines, the brightest in the group and about equally bright—but the more refrangible one rather the brighter—which form the termination of the group towards the blue; a line nearly as bright about the middle of the group; and a third prominent line at the end of the group towards the red.

We have little doubt, though we hesitate to state it positively, that the space between the two brightest lines, that on the blue side of the bright line in the middle of the group, and the spaces

on the blue sides of some others of the lines were darker than the faint luminous background, in which case we should have to do possibly with lines of absorption of the same substances shifted towards the blue. A few only of the finer bright lines which were occasionally glimpsed between the more brilliant lines have been put into the diagram.

The pair of bright lines at the termination of the group towards the blue makes this the brighter end of the group, which does not however, as a whole possess any of the usual features of a fluting.

On February 10, the micrometer webs were placed so as just to include the bright lines of the group, but not the faint background which at the clearest moments could be traced for some distance, especially at the blue end of the group. The instrument remained untouched, and the position given in the diagram is that found from the places of the micrometer webs upon the solar spectrum, on Rowland's scale, as observed on the following morning.

On the 26th, measures of this group were made relatively to the position of the principal line in the nebula of Orion; these gave also almost exactly the same position in the spectrum for the group, but, as we have already stated, all these measures are unfortunately liable to a small error from the possible flexure, at that time, of a part of the instrument.

The mean of Mr. Campbell's measures at the Lick Observatory, during the period of our observations, from February 10 to February 27, gives λ 5006 for the middle of the band. He remarks: "In any discussion of these observations it is necessary to take into account the difficulty of accurately locating the centre of a line so broad and diffuse as this one is."*

In another place Mr. Campbell says: "The line is at least 8 tenth-metres broad and the edges very diffuse."†

These observations would be brought into accordance with our own, so far as relates to the length and the position of the band, if we suppose Mr. Campbell to have observed, only the more refrangible and much brighter half of the whole group.‡

The probable analogy between the Nova and the remarkable variable star β Lyræ, in the spectrum of which also, we have to

* Astronomy and Astro-Physics, May, 1893, pp. 418, 419.

† *Publ. Ast. Soc. Pacific*, vol. 4, p. 246.

‡ Professor Campbell also says: "On August 30 the line was suspected to be double, and the grating measures of that night refer to a point midway between the two condensations. On September 7 the measures refer to a point of maximum brightness slightly less refrangible than the centre of the line."—Astronomy and Astro-Physics, Oct., 1892, p. 718.

do apparently with bright and dark lines of the same substances, though not in all cases identical with those of the Nova, in motion relatively to each other, which we ventured to point out in our former communication on the Nova,* has been recently greatly strengthened by the photographic observations of β Lyræ at different stages of its periodic variations by Dr. Bélopolsky at the Observatory of Pulkova.

In some of his photographs, especially in one taken shortly after the star's second maximum, bright lines come out near the positions of the bright groups of the Nova which are now under discussion. As the scale of Dr. Bélopolsky's photographs is much smaller than that of our diagram, we felt some hesitation in attempting any identification of his lines with those of the Nova. At our request, Dr. Bélopolsky has been so kind as to put into our diagram the two brightest of the lines of β Lyræ, as they appeared shortly after a second maximum, which fall within the brightest group of the Nova, and which, indeed, may be identical with two of the lines in the Nova. It may, however, be thought that the lines of β Lyræ suggest that they are independent bright lines rather than members of a group such as that of the Nova.

Whatever may ultimately be found to be the truth, there can be no question as to the probable high significance of the remarkable analogy which exists between the changes which take place in β Lyræ and those which have been observed in Nova Aurigæ.

The two other spectra in the diagram represent respectively the position and character of the two nebular lines, and the position of the bright double or multiple band which was so brilliant in this region of the Nova in the beginning of last year.

2. *Bright Group near the Position of the Second Nebular Line.*

Not anticipating that our opportunities of observing were to be so soon cut off, we gave our attention chiefly to the brighter group, intending, after we had completed our observations and measures of it, to attack seriously the second group.

However, on nearly all the nights we observed we gave some attention to this group, which, from being fainter, is more difficult to resolve, though on the clearer nights it was fairly well seen with the grating.

Generally, the group may be described as of the same order as the brighter one, consisting of bright lines and possibly of some absorption lines upon a feebly illuminated background.

We have endeavoured to represent in the diagram as truthfully as we can the best views we obtained of this group; during one

* *Roy. Soc. Proc.*, vol. 51, p. 494.

or two exceptional moments of good seeing we thought that we glimpsed finer bright lines in the spaces between. Indeed, the group may consist of a close grouping of bright lines.

For the same reasons, fewer measures were attempted of this group, and its position was less accurately determined, but neither the constitution of the group as represented in the diagram nor its position can, we think, be much in error.

We were also unable to work upon the bright line in the orange, and to do more than satisfy ourselves, by a direct comparison, that the line about F was really the hydrogen line in that region.

General Conclusions.

It need scarcely be said that no contrast could well be more striking than that which these extended groups of lines form with the two narrow and defined lines in the spectrum of the great nebula in Orion.

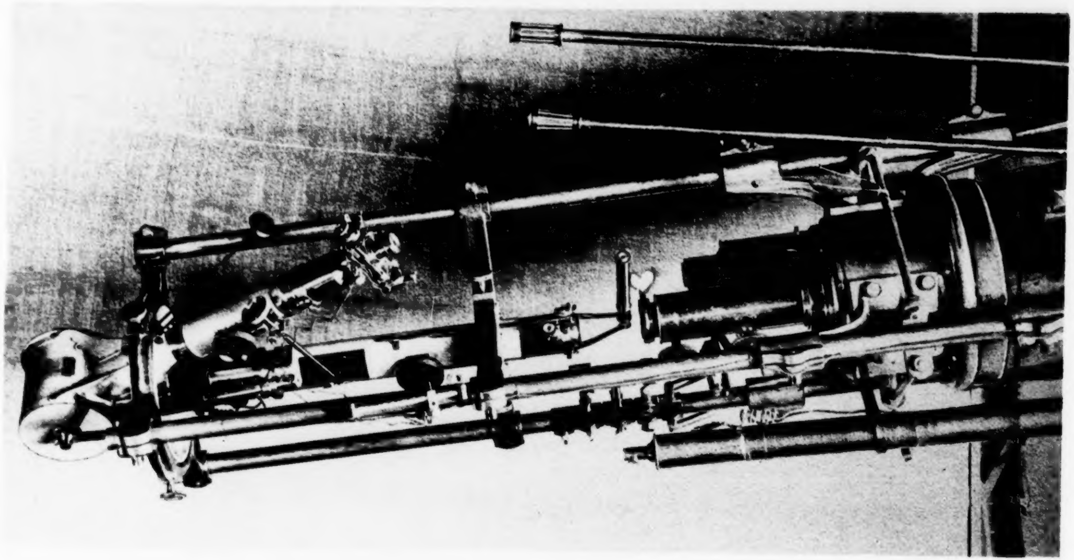
It is difficult to suppose that we have to do with the same substance or substances, whatever they may be, which produce the nebular lines, even if we imagine very different conditions of temperature, or even allotropic conditions.

In the laboratory, allotropic changes are not usually accompanied by new groups, or lines at the positions of the characteristic lines of the substances in their original state.

We wish to speak at present with great reserve, as our knowledge of the Nova is very incomplete, but we do not regard the circumstance that the two groups of lines above described fall near the positions of the two principal nebular lines as sufficient to show any connection between the present physical state of the Nova and that of a nebula of the class which gives these lines.

Influenced by the analogy between some of the changes in the spectrum of the Nova and those which are associated in the spectrum of β Lyræ with the variation of its light, and also by other reasons which we pointed out in our former communication, we are still strongly inclined to take the same view which we there ventured to suggest, namely, that in the outburst of the Nova we have not to do mainly with cold matter raised suddenly to a high temperature by a collision of any form but rather, for the most part, as was suggested by Dr. Miller and myself in 1866 in the case of the first temporary star examined with the spectroscope, to an outburst of existing hot matter from the interior of the star or stars; indeed, to phenomena similar to, but on an immensely grander scale than those with which we are familiar in the peri-

PLATE XXXIV.



THE TULSE HILL SPECTROSCOPE.

odic greater and lesser disturbances of the Sun's surface.

Such grand eruptions may well be expected to take place as stars cool, and if in two dull and comparatively cool stars such a state of things were imminent, then the tidal action due to their near approach might be amply adequate to determine, as by a trigger action, such eruptions.

Under such conditions, fluctuations of brightness and subsequent partial renewals of the eruptive disturbances might well take place.

THE MODERN SPECTROSCOPE.

VIII.

*The Tulse Hill Spectroscope.**

WILLIAM HUGGINS.

This instrument was designed primarily for the purpose of mounting upon the 15 inch Refractor belonging to the Royal Society, a fine 4 inch Rowland grating which was furnished to me by Mr. Brashear.

A condition of fundamental importance in the adaptation of the spectroscope to the telescope is that the instrument shall remain perfectly rigid in all its parts relatively to each other, and also to the optical axis of the telescope, in all positions of the telescope. It appeared to me that this condition would be most certainly secured by making the spectroscope complete and rigid in itself, independently of its attachment to the steel tubes, by which it is supported. The spectroscope if removed from the telescope would remain a complete and rigid instrument.

The firm attachment of this spectroscope to the telescope is carried out by means of three steel tubes 1⅜ inch external diameter, which slide in three long brackets strongly bolted to the iron eye-end of the steel tube of the telescope. These tubes, as can be seen in the photograph, are further held together and formed into a stiff supporting cage by two iron ring brackets through which they pass. The ring-bracket near the ends of the tubes supports the heavy part of the spectroscope, consisting of the grating and prism box; the other ring-bracket supports the collimator near the slit end, and strengthens the tube-cage near the middle of its length.

* Communicated by the author.

By means of adjusting screws in these ring-brackets the axis of the collimator can be brought into line with the optical axis of the telescope. The other necessary adjustments are also provided for. By the large milled head on the top of the collimator, the spectroscope, as a whole, can be moved so as to bring the slit to the focal plane of the object glass for the part of the spectrum under observation; and a fine graduation on the sliding tube enables this adjustment, and also any similar adjustment that may be required for changes of temperature to be found at once after the necessary data have been obtained. The adjustment of the collimator lens can be made by a smaller milled head. By an arrangement, which explains itself in the photograph, the collimator and telescope can be focussed simultaneously.

The collimator, and the telescope, fixed at an angle of 25°, are firmly attached to the grating-box, and are further secured from relative flexure by a gun-metal collar fitting into the iron ring-bracket.

The grating is mounted in an air tight metal case, provided with shutters to open when it is in use. This case slides into the box against a fixed point so as to secure the grating always taking up the same position. A prism of 37° silvered on one face, similarily mounted can take the place of the grating when small dispersion is required.

The grating, or prism, is moveable about the axis of the box, by a rod which is placed conveniently for the hand of the observer. At the top of the box, which is strengthened internally by metal compartments, a sector is fixed on the moveable axis, which is graduated on silver, and is read by a small telescope. The graduated edge of the sector, which can be illuminated by a small incandescent lamp, is divided into spaces of 5′, and reads by the aid of the vernier to 10″.

The telescope of the spectroscope is provided with a micrometer by Troughton and Simms, the fine webs of which are very successfully illuminated simultaneously from both sides from one small incandescent lamp, on an original plan devised by them. The amount of illumination can be varied by means of a small resistance coil to suit the object under observation. With the feeble illumination which is necessary for most celestial objects, it is not easy to read the number of whole revolutions of the micrometer screw, in the usual way, from the teeth of the comb. A simple form of a revolution-counter is geared into the outer rim of the micrometer head, and turns with it without sensible friction. The micrometer heads and their revolution-counters can be illuminated at pleasure by means of two small moveable incandescent

lamps suitably placed above them. The micrometer-screw has 100 threads to the inch; and when the second order of the grating, ruled to 14,438 to the inch, is in use, about $\frac{23}{000}$ of a revolution are equal to one tenth-metre.

The collimator and telescope have thin cemented lenses of 2¼ inches diameter; that of the collimator is provided with a diaphragm reducing it to 2 inches, which is its effective aperture; as the collimator has a focal length of 24 inches, and the object-glass of the telescope a ratio of $\frac{f}{12}$. The telescope of the spectroscope has a focal length of 18 inches, and is provided with four eyepieces magnifying respectively 12, 18, 22 and 29 diameters.

For photography the eye-part of the telescope can be replaced by a camera, and the whole instrument rotated through 90°, so as to bring the length of the slit in the direction of the star's motion.

The grating-box can be uncoupled from the collimator and removed from the supporting iron ring, and replaced by a battery of glass prisms, the same telescope and micrometer, or photographic lens and camera, being then attached.

A novelty in this instrument, which will be seen at once to be one of great practical importance, consists of a simple but very effective arrangement by which a star can be brought at once, and kept steadily, within the jaws of the slit. For my primary photographic work on the spectra of the brighter stars, I devised in 1875 a method of bringing and keeping a star within the slit, which is figured and described in my paper "On the Photographic Spectra of the Stars," (*Phil. Trans.* 1880 p. 673):

"A round thin plate of polished silver, 1½ inch in diameter, with a narrow opening in the middle rather longer and wider than the slit itself, was fixed over the slit of the spectroscope. This forms a plane mirror, and when the telescope has been brought approximately into position by its finders, the bright image of a star is seen somewhere upon the plate by looking into a Galilean telescope fixed in the place of the eye-piece of the Cassegrain telescope. Now if at the same time artificial light is thrown upon the plate, it becomes itself visible and thus the opening in it, and the slit within the opening can be distinctly seen at the same time as the image of the star as a bright point upon it. By the aid of this arrangement there is no difficulty in bringing the star's image by the slow motion handles of the equatorial readily, and with precision upon any part of the slit. As the position of the star's image even upon the slit itself can be seen, the

image being somewhat wider than the slit and therefore not wholly lost within it, it is possible to keep the star in view upon the slit during the whole time the photograph is being taken; and to correct instantly by hand any small departure of the star's image from its proper place upon the slit."

Some improvements, and modifications of the original plan have been made to suit the conditions of a spectroscope applied to a refracting telescope. Slit-jaws of speculum metal have been substituted for the silver plate used in 1875. This metal answers the purpose admirably as it receives and maintains a high polish, and can be fashioned to take very smooth and true edges for the slit.

If the polished surfaces of the jaw-plates were in a plane perpendicular to the optical axis of the telescope, the light after reflection would return upon its path. The plane in which these surfaces lie is, therefore, slightly inclined so as to throw the reflected light sufficiently to one side of its original direction to be caught by a suitably formed reflecting prism placed just outside the converging rays from the object-glass. This prism is provided with a suitable optical arrangement of some magnifying power, and is shown in the photograph, in position for use.

At night, when the telescope is directed to the heavens, if the eye is placed at this reflecting eye-piece, a field of stars of about 5′ in diameter is seen together with the slit crossing it. Very often the faint illumination of the sky is sufficient to enable the slit to be seen, but if necessary, a feeble artificial light can be thrown upon the polished surfaces, so as to make the slit visible, but without interfering with the visibility of the images of even faint stars. It is obvious that by means of this arrangement it is quite easy to bring, and also to keep steady a star image upon any part of the slit. In the case of suitable double stars wider than about 3″, component images are seen well apart, and either of them can with ease be brought and kept within the slit-jaws. So also in the case of planets and nebulæ there is no difficulty in selecting any small part of one of these objects for separate spectroscopic examination.

This reflecting eye-piece is hinged, and when not in use can be turned down out of the way to give room for a large diagonal eye-piece for viewing celestial objects directly, without removing the spectroscope from the steel tubes.

The slit is also provided with the usual reflecting eye-piece, which can be pushed in behind it. I pointed out in my paper of 1879 (*loc. cit.*) that in photographing the spectra of the stars the

necessary breadth can be most conveniently obtained by the plan now universally employed, of giving a small motion to the star's image in the direction of the length of the slit. For eye observations it is still necessary to have recourse to cylindrical lenses. For a great number of years I have minimised the inconveniences which such lenses introduce by using the plano-concave instead of the usual plano-convex form.

Perhaps the least objectionable way of using them, is to have three, or more, of different cylindrical curvatures fitted into a small brass slide, which goes immediately in front of the eye-lens, and fits equally the different eye-pieces. The lens giving the most suitable breadth can be brought into use, and if it be of concave form, without in the least disturbing the focal adjustment of the eye-piece.

If it be preferred to place the cylindrical lens before the slit, the advantage in respect of light will be seen to be in favor of the plano-concave form.

The arrangement for comparison spectra is attached to one of the rods, a reflecting prism of 90°, sending the light upon the small moveable prism immediately in front of the slit. The optical arrangement is such as to completely fill the lens of the collimator with the light which furnishes the spectrum for comparison.

I cannot refrain from expressing my admiration of the great rigidness of every part of the apparatus, as well as of the extremely fine definition both when the prism and the grating are in use; for which the highest credit is due to Messrs. Troughton and Simms; and also to Mr. Brashear for the high qualities of the grating.

I ought to add that a second spectroscope, containing some new points of importance is now in course of construction for use with the 18-inch Cassegrain telescope, for the photography of the ultra-violet spectra of celestial objects.

PHOTOMETRIC OBSERVATIONS OF THE PLANETS.*

EDWIN B. FROST.

An important contribution to the rather neglected subject of planetary photometry has been made by Professor G. Müller in No. 30 of the Publications of the Astro-Physical Observatory at

* Communicated by the author.

Potsdam under the title " Determinations of the brightness of the larger planets and several of the asteroids."

The observations included in the memoir were made exclusively with the Zöllner photometer, and extend over a period of eight years, only such evenings being utilized as were meteorologically above suspicion.

The object of these researches was to test the correctness of the various theories of the variation of brightness of planets with their change of phase; to discover analogies between the different planets in respect to their reflecting power: and to obtain data for the investigation of certain closely related subjects, such as the constancy of the light emitted from the Sun, and the existence of an absorbing medium within the space occupied by the solar system. We may perhaps best state the results on these two points at once. Since the brightness of the planets is measured by comparison with stars, it is plain that any periodic variations in the brightness of the Sun—so difficult to determine directly—will be mirrored in the measured brightness of the planets, which moreover should all be correspondingly affected. Now on combining his results into yearly means, Müller finds evidences of such variation, particularly in the case of Jupiter, which cannot be attributed to the uncertainty of the measurements. This could be accounted for by a periodic change in the transparency of the Jovian atmosphere, but similar though less pronounced variations in the case of Mars, Saturn and Uranus give weight to the former interpretation.

Müller finds that if an absorption occurs at all in the space within the solar system, the density of the absorbing medium must be considerably under one thirty-millionth of that of the Earth's atmosphere at sea-level.

A first requisite of these investigations was an exact knowledge of the magnitudes of the comparison stars used. (A star near the planet, and of as nearly the same magnitude as possible, was employed for comparison). Accordingly the magnitudes of 14 standard stars brighter than the 2d mag., used with the brighter planets, were very carefully compared, pair-wise, and then combined and connected all together. The brightness of the pole star was taken as 2.15, so that the scale is the same as that of the H.P. 42 fainter stars employed for comparison with the fainter planets were treated in a similar manner, so that an independent catalogue of the magnitudes of 56 stars was obtained, which in most cases quite fully confirmed the results of the H.P.

The probable error of the value for a star of the brighter group was about $\frac{1}{30}$ mag., and for the others about $\frac{1}{20}$ mag.

In these measurements the correction for atmospheric extinction was taken directly from a table previously made from a great number of observations at Potsdam. Müller considers this procedure more satisfactory than that adopted by Pickering of obtaining the co-efficient of extinction for each night, as the data for its determination must then be few, and the practice of utilizing only the clearest nights makes in his opinion the tabular values more reliable.

The results communicated in the memoir may be briefly summed up as follows:

The formulæ of Euler, Lambert and Seeliger are all inadequate to express completely the variation of brightness of a planet with phase, though Seeliger's theory is the best from a theoretical as well as practical stand-point.

The empirical expression, found by Müller for the brightness of the planets at any time are as follows, (α being the angle of phase and everything being expressed in magnitudes).

Mercury	$B = -0.901 + C + 0.02838\,(\alpha - 50) + 0.0001023\,(\alpha - 50)^2$
Venus	$-4.707 + C + 0.01322\alpha + 0.0000004247\alpha^3$
Mars	$-1.787 + C + 0.01486\alpha$
Jupiter	$-2.233 + C$
Saturn	$0.877 + C + 0.0436\alpha - 2.5965 \sin A + 1.2526 \sin^2 A$
Uranus	$5.863 + C$
Neptune	$7.661 + C$
Ceres	$6.909 + C + 0.0423\alpha$
Vesta	$6.006 + C + 0.0266\alpha$

For the first two planets $C = \frac{1}{0.4} \log \frac{r^2 \Delta^2}{r_0^2}$; for the others

$$C = \frac{1}{0.4} \log \frac{r^2 \Delta^2}{r_0^2 (r_0 - 1)^2}$$

where r is the distance from the Sun to the planet at the time and r_0 is the mean distance, and Δ is that from Earth to planet. The minus sign indicates a negative magnitude, the object being brighter than the 0 mag. In the case of Saturn the angle A is the elevation of the Earth above the plane of the ring.

The variations of brightness of Mercury do not at all agree with theoretical values, but correspond very closely with Bond's observations of the Moon. Müller concludes that Mercury has no atmosphere or only a very slight one. (It will be remembered that the spectroscopic evidence of such an atmosphere is by no means conclusive). He does not share the optimistic views of

some that the knowledge of the substances causing the reflection may be gained from the comparison of the light-curve of the planet with the optical behavior of diffusely reflecting terrestrial substances.

The observations show no connection between the brightness of a planet and its axial rotation, and no variation of the asteroids such as to indicate a rotation.

The relative albedos of the various planets in terms of that of Mars are found to be as follows, with Zöllner's values added for comparison:

	M.	Z.		M.	Z.
Mercury	0.64	0.43	Saturn	3.28	1.87
Venus	3.44	2.33	Uranus	2.73	2.40
Mars	1.00	1.00	Neptune	2.36	1.74
Jupiter	2.79	2.34			

In conclusion Müller deduces the radii of the 17 minor planets which he observed, on the two assumptions, first (and most probable) that their albedo is the same as that of Mercury, and second, that it is the same as that of Mars. We cite a few of the values, according to the two hypothesis:

	I	II
Ceres	R = 475 km	R = 379 km
Pallas	354	282
Vesta	473	377
Hebe	159	127

The investigations communicated in the memoir are a part of an extensive photometric campaign which has been in progress for some time at Potsdam. The accuracy attainable with the Zöllner photometer and the well-known skill and thoroughness of the observers justify the interest with which the appearance of further results will be awaited.

ON CERTAIN TECHNICAL MATTERS RELATING TO STELLAR PHOTOGRAPHY.*

MAX WOLF.

The Change of Sensitiveness in Dry Plates.

In no kind of photographic work is a knowledge of the sensitiveness of dry plates of such importance as in stellar photog-

* The following is a free translation of an article in Eder's Jahrbuch für Photographie und Reproductions-technik, by Dr. Max Wolf, of Heidelberg, whose admirable work in stellar photography is so well known. We do not think that

raphy. Generally, a photographer has merely to remove the cap of his lens, replace it, and the operation is complete. If the exposure proves to be too short he gives another and longer one; or he takes at once two plates with different exposures.

With the astronomer the case is very different. For him the chief part of the work lies between the opening and closing of the shutter, for in the interval he must keep his camera directed with the most careful attention, often for hours, to the moving stars which the imperfect clockwork of his apparatus will only approximately follow. What that means, only he who has tried it can tell. It is easy to imagine that under these circumstances a very sensitive plate is welcomed by the astronomer. The tedious work of exposure is proportionally shortened.

But it is not a pleasant experience to give an eight or nine hours exposure to what is believed to be a highly sensitive plate, and then to find on development that the whole work has been thrown away, because the plate was really a quite insensitive one. The photographer who has had this experience repeated several times, (as I have), very soon learns to become cautious. The only reliable test of sensitiveness, however, as I may here remark, is comparison by actual exposure to stars, the ordinary sensitometer tests being much too uncertain.

Special caution is necessary in dealing with fresh plates. In the early part of my work I always noticed that new plates received from the makers were uniformly less sensitive than the previous ones, and that it was necessary to expose them a much longer time, so that it almost seemed as if the manufacture of dry plates was retrograding. The plates which I principally used were those of Lumière, Schleussner, Beernaert, and Wratten and Wainwright. They all showed this apparent decrease of sensitiveness, the Lumière plates most strongly, those of Schleussner in a less degree. The peculiarity is so strongly marked that during the last winter I was hardly able to obtain the same objects on a new lot of Lumière plates that I had previously obtained with the last plates of the same make, even with a threefold greater exposure. Stars and nebulæ which I had photographed easily in one hour, hardly appeared on the new plates after an exposure of three hours.

I had indeed known earlier than this, that plates changed some-

the difficulties described by Dr. Wolf in connection with lenses have been generally met with in this country, probably for the reason that lenses designed for stellar photography have almost always been made by astronomical opticians, who are familiar with the precautions which must be observed in mounting large telescope objectives.

what in sensitiveness when stored, but I could hardly expect that the change would amount to so much as a threefold increase; and yet it was so. After five months the new Lumière plates, at first so slow, were as sensitive as the preceding ones, and exceeded in sensitiveness all my other plates. A similar change took place in those of other makers. The orthochromatic plates seemed to have a smaller tendency to changes of this kind.

The sensitiveness does not by any means increase indefinitely with the time. On the contrary, it soon reaches a maximum, which persists for some time, and after this the sensitiveness diminishes. Hence it became a rule to test each kind of plate, in order to determine when it was in its most sensitive condition.

For Lumière plates this time has been found to be from five to seven months after manufacture. By taking advantage of this fact, much can be gained; sometimes, as I have said, an increase in sensitiveness of three or four times. Whether the period of ripening is always quite the same under similar processes of manufacture is somewhat doubtful, and the question must be left undecided.

From the foregoing the astronomer may take warning never to assume that plates made from the same emulsion are equally sensitive, if they are used at different times. The sensitiveness of the emulsion differed, in the cases mentioned, according to the time when the exposure was made. For the same reason it is also very difficult to determine beforehand what exposure should be given in order to obtain stars of a certain magnitude. It is quite impossible to do this, (leaving out of the question changes in the transparency of the air), without taking into account the age of the plates.

On the mounting of large photographic objectives.

The proposition may be stated, that for testing a photographic objective there is no method in any way so satisfactory as that of photogarphing stars. The faults of the objective are brought out conspicuously, so as to be visible at a glance, as they are by no other method.

It is especially astonishing to see how small the flat field is, which the objective will define sharply. Portrait lenses, as well as wide-angles and aplanatics, have a really quite frightfully small field free from aberration. If a four-inch portrait combination of the best make will define perfectly a space 2¼ inches square without a stop, it must be regarded as performing very satisfactorily. A four-inch Euryscope by one of the best op-

ticians, without a stop, does not by any means cover a plate $3\frac{1}{2} \times 4\frac{3}{4}$ inches; and with an otherwise perfect five-inch aplanatic lens I could hardly exceed a plate of this size. So with the other qualities of objectives, and I will show at another time how the spherical aberration of an object-glass, in particular, can be determined by this method with great accuracy. I wish here to speak of another defect of object-glasses, which can be easily corrected, and which nevertheless, although it is very detrimental to sharpness even in ordinary photography, has hitherto received but little attention. I mean the distortion of an image due to pressure on the lenses by the cell in which they are mounted.

For my experiments on this subject I had a number of lenses, $2\frac{1}{2}$, 3, 4 and 5 inches in diameter, by the best makers, and I must say that all, without exception, showed this defect, in most cases very strongly.

Last year, (for I will relate here the history of my sorrows), after I had used a number of smaller instruments for some time, I came into possession of a five-inch aplanatic lens, and mounted it on my refractor. The flange of its mounting was provided with screws, by which it was ordinarily attached to the camera. On my refractor there is, however, a strong brass bracket ($1\frac{1}{2}$ to 2 in. thick and weighing 30 lbs.), and on the front turned surface the flange of the mounting was secured by its screws, while the camera was fitted to the other side. The five-inch lens in its cell was then screwed into the mounting. After focusing, I tried it on the stars and obtained atrocious images.

With a perfect objective the photographic image of a star is, as is well known, a very small circular disc, which becomes larger and larger as the time of exposure is prolonged. Instead of small circles I obtained images which had an irregular appearance. At first I thought that the principal cause of these distorted images must be imperfect centering of the lenses, and made a series of investigations in this direction. I photographed a star several times with different adjustments for focus, and in this way obtained images, representing cross-sections of the cone of rays from the lens at different places, which were not circular, but angular, and quite irregular in shape. These experiments were very interesting, but still they did not lead in the right direction. The maker of the aplanatic lens, to whom I sent plates and copies, afterwards centered the lens in the most exact manner. I myself placed the plate exactly at right angles to the optical axis, but all in vain. It very soon appeared, however, that turning the lenses in their cell changed the position of the irregulari-

ties in the image. This at first led me again to regard imperfect centering as the cause of the defect, and I was much perplexed to know what I should do next, inasmuch as not the slightest error of centering could be detected by optical methods.

I now changed the object of the investigation; I tried other objectives in the same way, taking star photographs with a four-inch portrait combination of known excellence, by a Parisian maker, a 2½-inch aplanatic made in South Germany, and a four-inch Euryscope. In this way I was soon led to the cause of the bad images. Not that these lenses did not have the same defects; on the contrary, the portrait lens depicted the stars as blurred, but still easily recognizable hexagons, the aplanatic lens as triangles, and the Euryscope as distorted pentagons. Now the mounting of the portrait lens was secured with six screws, that of the aplanatic with three, and that of the Euryscope with five screws.

I now took the five-inch aplantic again, and screwed tightly home the five screws of its mounting. (Before, they were only loose, and strips of felt had been placed under them.) The result was that I obtained beautiful five-pointed stars.

But even when I left the screws so loose that the mounting of the aplanatic could rock, the points of the image could still be recognized, although they were greatly reduced in strength. It further became evident that some other distortion must be present, superposed on that caused by the screws, which obscured the latter when the screws were loose. It was for this reason that I was not at first able to recognize the fact that the distortion was caused by pressure on the glass.

In order to be certain of the extent to which the bending of the lenses was produced by the strain of the screws, a very thick mounting (a brass ring more than an inch thick) was made for the lenses, and secured loosely to the bracket with three screws, which passed through three slight projections, so that the mounting was supported at only three places. The lenses of the aplanatic were so much loosened in their cells that they could be made to rattle, in order to free them from any strain. The result was that the stars, aside from the distortion previously referred to, were triangular.

The cells of the lenses were then strengthened by the maker. I hoped further that by putting a large number of screws in the mounting, the angles of the image could be distributed, and would perhaps no longer be apparent. But the strengthening of the cells of the glasses was of no avail; six screws give six promi-

nent angles, and nine screws just as distinctly nine angles. It should be borne in mind that the mounting was an inch thick, and that it was turned to fit the surface of the bracket; that the screws were always set up by hand and never with a screw-driver, and hence were certainly loose; that, finally, the lenses were loose enough to rattle in their cells, and nevertheless the glasses were bent out of shape.

In regard to the position of the star points, it should be noted that the points were always in the angles between the lines drawn from the center to the screws. If, for example, the objective was secured with three screws, the star image was triangular, with the points lying in planes passing through the optical axis and bisecting the angles between the screw-heads. Finally, in order to conclude these experiments, I resolved on an infinite number of points; that is, I soldered a heavy mounting to the bracket, and afterwards cut in it the thread for the cells of the aplanatic. When this was done, behold! there were no more points on the stars.

The independent distortion previously discovered still remained, however, and it was now possible to undertake the correction of this also.

Since the lenses appeared to be quite free in their cells, the pressure causing the distortion was apparently due to the unequal distribution of the weight of the lenses on the points of support. It was easy to trace and correct the fault in this case, from a consideration of the manner in which the telescope lenses were mounted. The cells were so arranged that the lenses rested on three points of their periphery, and were held in position by an elastic ring, which pressed them against the points of support. The same construction is applied with equal facility to portrait lenses. In the case of those aplanatics in which a small meniscus is cemented into a larger one its application is more difficult. A thin metal ring must then be cemented to the periphery of the larger meniscus, extending slightly inward over the smaller one—a construction which is also occasionally adopted for other reasons. The elastic ring is then made to press against this ring of metal.

In most cases it is naturally sufficient to alter the arrangement of the cells as just described, since the influence of the screws in the flange of the mounting is removed at the same time. My course was that offered by the character of the investigation. Later I made only this second change. In this manner I have so improved all my objectives that they give the circular star images required.

It should not be supposed that these distortions of an image are only of importance in astronomical photography, where great accuracy is necessary. The photographs of ordinary terrestrial objects were materially improved after I had mounted a rather large lens in such a manner that it was as free from strain as possible. The known inferiority of definition of large objectives as compared with smaller ones has its origin largely in this defect, which must be much more pronounced in large objectives, and larger stops could be used with plates of the same size, if more care were taken in mounting lenses in their cells.

SOME RECENT ATTEMPTS TO PHOTOGRAPH THE FACULÆ AND PROMINENCES.*

J. EVERSHED, JR.

Nearly two years ago, when I first succeeded in obtaining photographs of the Solar Prominences in F light, using isochromatic plates, the idea occurred to me to try and obtain images not only of the prominences on the limb, but also those which must be projected on the disk of the Sun, and for this purpose I proposed to exclude from the sensitive film all parts of the spectrum excepting the dark line F, which would be made to coincide exactly with a narrow slit in a screen placed in front of the plate; and it was the reversals of this line, or rather the variations in intensity, that might occur while the Sun's image was allowed to transit the spectroscope slit, which were to record themselves on the sensitive plate, to which a corresponding motion would be given by clockwork or otherwise, in order that the successive images of the F line should fall on different parts of the plate and so build up, as it were, a continuous and complete image of the whole disk in absolutely monochromatic light.

I was rather deterred from carrying out this idea on considering that, after all, the chromosphere which envelops the whole surface of the Sun is itself brighter than most of the prominences, and consequently the intensity of the hydrogen lines would not probably be very different even where prominences overlaid the chromosphere. In other words, there would be no contrast sufficient to make the forms visible when projected on the brighter background, any more than in the case of Jupiter's satellites, which usually become invisible during transits, as soon as they have entered a short distance within the planet's limb.

* *Journal, British Astronomical Association Vol. III. No. 6.*

Recently, however, Professor Hale's discovery that the two calcium lines H and K are not only brightly reversed in the prominences, but also in irregular patches on the disk corresponding to the faculæ, has induced me to make the necessary arrangements and alterations in the spectroscope so as to obtain monochromatic images as above described, only using H or K light instead of F; this being essentially Professor Hale's method of photographing the faculæ. I still think it may be worth while to take photographs in F light and compare these with the K images, but it is quite certain that the ordinary faculæ will not be shown as they do not reverse the hydrogen lines.

In a preliminary way I have obtained numerous photographs of the spectrum of portions of the solar disk including spot-regions, faculæ, and prominences; the results, so far, seem to agree in all respects with Professor Hale's recent work. Thus I have found that all hydrogen prominences reverse H and K brightly, and the forms in these lines are the same as in C. Also on the disk the calcium lines are frequently reversed, and sometimes doubly reversed over large areas, and there is no doubt that these reversals correspond with the faculæ, for when the latter show in the spectrum as bright bands parallel with the dust lines, H or K are always bright where the bands cross them.

The first successful photographs in K light, of the whole disk by the transit method, using the grating belonging to this Association, were obtained on February 19, this year, and these show an enormous mass of faculæ surrounding and following a large spot a little past the central meridian in the southern zone; the K reversals cover an area of, roughly, 500 square degrees of the Sun's surface in the neighborhood of the spot, and besides this there is shown a series of faculæ crossing the disk from the N. E. to near the W. point in the latitude of the northern spot zone. Photographs taken at later dates show in general the two series of faculæ crossing the disk in the two spot zones. The large group of February 19 was photographed again on March 12 and 19, after a rotation, and these negatives show that whilst the spot itself had become more conspicuous, the faculæ surrounding it were much fainter, and appeared to be breaking up into scattered fragments.

With regard to prominence photography, I have obtained fairly successful negatives by simply photographing a portion of the spectrum, including either the F hydrogen line, or, better still, H to K, and opening the slit as wide as circumstances will allow keeping the Sun's limb stationary a few seconds off the edge by

clock movement. In this case I find that four or five prisms (of 60°) are much more suitable than a grating, as the loss of light is far less, and the exposure may be cut down to even a small fraction of a second, thus reducing atmospheric tremors and irregularities in the driving clock to a minimum. Using a semicircular slit in this way, it has been found possible to photograph 90 degrees or more of the limb showing chromosphere and prominences; but it requires great care to get the Sun's image exactly concentric. The plan I adopt is to take advantage of the undispersed white light reflected from the first surface of the first prism. A long focus lens (I use a spectacle lens of 2 feet focus) is placed near the first prism in the course of the reflected rays, which are thereby brought to a focus at a little distance from the instrument; a piece of white paper is placed sufficiently near the focus to show a sharp image of the slit, the R. A. and Dec. slow motions are then moved until the image of the Sun's limb is seen to just overlap the slit equally in all parts of the half circle. As the slit has to be adjusted in the focal plane of the refractor for the region of the spectrum near K, the white light image will be slightly out of focus, and must therefore be made to overlap the edge of the slit slightly, to ensure that the K image is exactly concentric.

I propose during this year to try and photograph the prominences by the transit arrangement designed for photographing the faculæ, but using four prisms instead of the grating, and limiting the field to a portion only of the limb; by this means I hope to get sharp and dense images of single prominences on a scale of 3 inches or more to the solar diameter.

To succeed in this it will be necessary to observe the K line visually, in order to bring it into exact coincidence with the slit. I do not anticipate much difficulty, however, in making this adjustment, as the prismatic spectrum is very bright, and K is easily seen when the eye is not fatigued. When a grating is used, one can make use of the overlapping spectra; thus, to bring the third order K on the slit, the second order D, which is very easily recognized, must be made to nearly coincide, the distance of the centre of the slit from D′ being made almost equal to that between D′ and D″.

This depends on the fact that three waves of K light very nearly equal in length two D waves, the yellow and violet light being superposed; whilst the latter only impresses the sensitive film.

The instruments I have used in making these experiments in

solar photography consist of an equatorial retractor of 2½ inches aperture only; it is provided with a spectroscope in which either a grating or a prism train can be used. A small plane mirror, placed just to one side of the collimator lens, receives light at a very low angle from the grating, and reflects it into an observing telescope of ¾ inch aperture and seven inches focus, placed in a convenient position for visual work. Another similar telescope is attached on the other side, its O.G. being close alongside the collimator lens; this receives light direct from the grating at an angle of diffraction of about 15°. The photographic plate-holder is attached about four inches behind the eye-piece of this telescope where the monochromatic image of the Sun is formed; this is either about four or eight times larger than the image on the slit-plate, according to the eye-piece used. The plate-holder, when attached to the eye-piece is also firmly clamped to the body tube of the refractor, thus securing perfect rigidity, the whole spectroscope being previously fixed in position angle, so that the two slits are perpendicular to the Sun's motion. The plate is made to slide across the slit admitting the K light by means of a cord drawn by a weight, the requisite uniformity of motion being secured by attaching the sliding frame to a piston working in a cylinder of 1 inch bore filled with water; a small hole in the piston allows the water to slowly pass from one end of the cylinder to the other during the stroke, and a valve also in the piston allows the water to pass freely back again on the return stroke. The speed can be varied to suit the varying time of transit of the solar image by altering the weight; with a given weight the speed will be nearly constant, depending only on the rate of flow of the water through the small hole in the piston, which can hardly vary appreciably with ordinary changes of temperature. With the weight properly adjusted, monochromatic images may be obtained free from all distortion, excepting that due to the slight curvature of the K line, and this is practically inappreciable, and can be allowed for if necessary.

In conclusion, I should like to refer anyone who might wish to take up this branch of solar work to the very interesting article by Professor Hale on the spectroheliograph, in the March No. of ASTRONOMY AND ASTRO-PHYSICS. In this he not only describes his own methods, which are certainly by far the best yet devised for monochromatic solar photography, but he also gives an account of all other similar proposals and attempts made in recent years, giving in fact, a complete history of the subject beginning with Professor Young's first attempts to photograph promin-

ences by means the of H_γ line and the wet collodion process, and concluding with his own latest devices, some results of which we have lately had the pleasure of seeing at a recent meeting of this association.

KENLEY, Surrey.

ON THE SUN'S ROTATION AS DETERMINED FROM THE POSITIONS OF FACULÆ.*

A. BELOPOLSKY.

Since the summer of 1891 I have obtained, by means of slow plates, a series of photographs of the Sun which show many details, and in which the faculæ are excellently defined.

I have selected a number of these plates and have studied especially those faculæ whose appearance changed very little during their time of visibility, so that they could be identified on different plates without doubt. This is confessedly a difficult task, since even in the interval of one day the form of a facula is likely to change beyond recognition. So that it is only exceptionally that a single point on a facula can be followed for more than two days. The positions of certainly identical faculæ were determined by a Troughton and Simms measuring engine, and the rectilinear co-ordinates were transformed into heliographic longitude and latitude by the tables of De la Rue and Spörer. I have attempted to use these determinations to obtain the daily rotation angle of the Sun. Of course, it is not possible by this means to fix a reliable numerical value for the angular velocity but it is possible to compare the angular velocity at the solar equator as determined by the Sunspots with the values obtained from my faculæ observations. According to Dr. Wilsing the angular velocity of the faculæ does not vary with heliocentric latitude.

In the following table I give the dates between which the faculæ positions are used; the limits of heliocentric longitude l; the heliocentric latitude b; the resultant angular velocity ζ_0; the sum of the intervals employed expressed in hours (column headed t); the angular velocity computed by Spörer's formula viz.:

$$\zeta_0 = 8.^\circ548 + 5.^\circ798 \cos b;$$

the difference $\zeta_c - \zeta_0$; and finally, the difference $14^\circ.27 - \zeta_0$; where $14^\circ.27$ is the angular velocity of the faculæ as determined by Dr. Wilsing.

* Translated from *Mem. Soc. Spectroscopisti Italian*, Nov. 1892.

Pulkowa 1891.	l	b	ζ_o	t	ζ_c	$\zeta_c - \zeta_o$	$14^\circ.27 - \zeta_0$	
	° °	°	°	°	°	°	°	
July 20-22......	234.9–269.8	− 23	13.65	98.13	13.88	+ 0.23	+ 0.62	
Sept. 3-4	279.5–302.3	+ 28	13.39	81.80	13.67	+ 0.28	+ 0.88	I
Id "	285.0–307.4	+ 27	13.11	81.80	13.74	+ 0.63	+ 1.16	
Id "	287.8–311.8	+ 24	14.13	81.80	13.85	− 0.28	+ 0.14	
Id "	285.1–308.9	+ 22	13.97	81.80	13.92	− 0.05	+ 0.30	
Sept. 3 4	290.5–300.8	− 22	13.60	18.15	13.92	+ 0.32	+ 0.67	II
Id. "	288.8–313.3	− 25	14.35	81.80	13.80	− 0.55	− 0.08	
Id. "	292.3–302.6	− 24	13.70	18.15	13.85	+ 0.15	+ 0.57	
Id. "	298.8–310.7	− 23	(15.70)	18.15	13.89	− 1.81	− 1.43	
Sept. 10-12......	49.6– 67.5	+ 26	14.12	30.40	13.39	− 0.36	+ 0.15	III
Id. "	288.0–305.8	+ 12	14.07	30.40	14.22	+ 0.15	+ 0.20	
Id. "	296.4–314.0	+ 11	13.90	30.40	14.24	+ 0.34	+ 0.37	
Sept. 12-14......	39.2– 77.3	+ 33	13.91	150.25	13.39	− 0.52	+ 0.36	IV
Id. "	39.0– 76.3	+ 35	13.62	197.04	13.30	− 0.32	+ 0.65	
Sept. 13-14......	63.9– 75.6	+ 30	13.61	42.91	13.57	− 0.04	+ 0.66	V
Id. "	66.8– 80.3	+ 27	13.70	42.91	13.71	+ 0.01	+ 0.57	
Id. "	64.0– 77.7	+ 28	13.76	42.91	13.67	− 0.10	+ 0.51	
Sept. 13-14......	61.0– 75.3	+ 22	14.29	42.91	13.92	− 0.37	− 0.02	VI
Id. "	65.9– 80.1	+ 19	14.25	42.91	14.03	− 0.02	+ 0.22	
Id. "	67.9– 80.4	+ 18	13.49	42.91	14.06	+ 0.57	+ 0.78	
Id. "	70.1– 83.9	+ 19	13.55	42.91	14.03	+ 0.48	+ 0.72	
Id. "	68.2– 80.4	+ 21	12.01	42.91	13.96	+ 1.95	+ 2.26	
Sept. 29-30......	74.0– 86.2	− 25	13.22	22.10	13.84	+ 0.58	+ 1.05	VII
Id. 30-31......	64.6– 89.5	− 21	12.78	46.74	13.91	+ 1.18	+ 1.49	
Oct. 3-3	311.6–325.0	+ 20	13.75	23.35	14.00	+ 0.25	+ 0.52	VIII
Id. 1-3	306.2–333.7	+ 25	13.26	96.55	13.80	+ 0.54	+ 1.01	
Id. 3	315.6–329.5	+ 28	14.19	23.55	13.07	− 0.52	+ 0.08	
Oct. 3-4	86.2– 93.2	+ 31	13.89	93.54	13.52	− 0.37	+ 0.38	IX
Id. "	70.0– 97.0	+ 25	13.48	93.54	13.80	+ 0.32	+ 0.79	
Oct. 3-4	78.4– 92.7	+ 21	14.70	23.41	13.96	− 0.74	− 0.43	X
Id. "	79.0– 93.1	+ 18	14.55	23.41	14.06	− 0.49	− 0.28	
Oct. 6-7	84.0– 97.0	+ 28	13.19	23.94	13.67	+ 0.48	+ 1.07	XI
Id. "	86.5–100.2	+ 31	13.75	23.94	13.52	− 0.23	+ 0.52	
Id. "	88.1–101.9	+ 28	13.85	23.94	13.67	− 0.18	+ 0.42	
Oct. 6-7	316.5–330.1	+ 22	13.55	23.94	13.92	+ 0.37	+ 0.72	XII
Id. "	318.4–343.8	+ 23	13.58	89.74	13.88	+ 0.30	+ 0.69	
Id. "	318.8–344.5	+ 24	13.74	89.74	13.85	+ 0.11	+ 0.53	
Oct. 6 7	320.4–345.0	+ 26	13.17	89.74	13.76	+ 0.59	+ 1.10	XIII
Id. "	319.8–345.6	+ 28	13.78	89.74	13.67	− 0.11	+ 0.49	
Oct. 7	314.0–326.0	+ 26	13.53	20.92	13.76	+ 0.23	+ 0.74	XIV
Id. "	319.7–331.9	+ 24	14.00	20.92	13.85	− 0.15	+ 0.27	
Id. "	317.6–329.7	+ 25	13.95	20.92	13.80	− 0.15	+ 0.32	

From this table it will be seen that all the angular velocities determined by me (excepting 5 out of the 42), are smaller than those of Dr. Wilsing, as is also evident from the signs of the column headed $14^\circ.27 - \zeta_0$. Most of the faculæ chosen lie in the zone $20^\circ - 55^\circ$. It is evident, therefore, that the rotation of the faculæ is smaller than the rotation of the equator as determined by spots; and smaller also than the value obtained by Wilsing working on his hypothesis. The differences $\zeta_c - \zeta_0$ have different signs, and the numerical values of ζ_0 are approximately those of the angular velocities of spots. The similarity is still more striking if we take the mean value of the several members of a group of faculæ. In this manner we can form from the table 14 groups as indicated by the brackets. One thus derives the following table, where the column ζ_0 indicates the mean angular velocity of the faculæ, and ζ_c, the same for the spots of corresponding latitude. In the first line of the table is placed a single isolated facula, which is entitled to greater weight than the others. The sums of positive and negative differences are almost the same.

	ζ_0	ζ_c	$\zeta_c - \zeta_0$		ζ_0	ζ_c	$\zeta_c - \zeta_0$
	°	°	°		°	°	°
	13 65	13.88	+ 0.23	VIII	13.73	13.74	+ 0.01
I	13.65	13.79	+ 0.14	IX	13.69	13.66	− 0.03
II	14.34	13.86	− 0.48	X	14.63	14.01	− 0.62
III	13.99	14.23	+ 0.24	XI	13.60	13.62	+ 0.02
IV	13 77	13.35	− 0.42	XII	13.62	13.88	+ 0.26
V	13.69	13.65	− 0.04	XIII	13 48	13.72	+ 0.24
VI	13.72	14.00	+ 0.28	XIV	13.83	13.80	− 0.03
VII	13.00	13.88	+ 0.88				

It may be objected to my determinations that the positions of the faculæ, which of course all lie very near the limb of the Sun, can be affected somewhat by refraction in the solar atmosphere. But in the first place, we have to deal only with differential positions, so that we may expect to find the greater part of the refraction eliminated. In the second place, the influence of refraction, if indeed any still remain, is such that the angular velocity obtained will be greater than the true value. I may add, what has long been known, that groups of spots are always surrounded by faculæ, and that both phenomena are intimately connected. It would, therefore, be a very remarkable thing if the rotation period of the faculæ differed in general from that of the spots, or from the overlying layer of the Sun whose rotation Professor Dunér has found to be almost identical with that of the

spots. I believe that the law of spot-rotation is applicable not merely to a thin stratum of the Sun, but to the rotation of the body as a whole.

PULKOVA, November 1892.

ON THE DETERMINATION OF THE SUN'S ROTATION FROM THE POSITIONS OF FACULÆ.*

DR. WILSING.

In the November number of the *Memorie della Societa degli Spettroscopisti Italiani*, Mr. Belopolsky published some measures of the positions of faculæ obtained from photographic plates. The discussion of these measures leads him to the conclusion that the law of rotation of faculæ is identical with that of spot rotation, a result which differs from that obtained by me, namely, that that stratum of the Sun which gives rise to the faculæ rotates with an angular velocity which is constant and therefore independent of the heliocentric latitude. His conclusion, however, appears to me from the following considerations to be scarcely warranted. In Mr. Belopolsky's series of measures, the greatest difference of time between two observations of the same object never exceeds two days. Now, in consequence of this small interval, the value of the rotation angle must be strongly influenced by errors both constant and variable. It would appear, therefore, somewhat hazardous to draw such conclusions from observations of 42 faculæ lying in the zone $\pm 11°$ to $\pm 35°$. Mr. Belopolsky is satisfied, however, with a comparison of his values with those computed from Spörer's formula for the angular velocity of spots, viz.:

$$\xi = 8°.548 + 5°.798 \cos b:$$

for he finds the sum of the differences between his observed values and those thus computed is practically zero, while the deviations between his observations and the constant angle of rotation found by me all lie in one direction.

I may here remark that the mere fact of the positive and negative differences adding up to zero is in itself no proof that the formula employed represents the physical fact; for there is an infinite number of formulæ which will satisfy this condition. We must add one other condition to be satisfied by the observation, viz., the deviations must not be systematic with reference to the

* Translated from *Astronomische Nachrichten*, No. 3153.

data; in other words there must be no "error of run;" the deviation must not depend upon the value of the argument. To test this in the present case, we may arrange the observations according to their heliocentric latitude. This I have done, preserving in the faculæ of the same latitude the chronological order of Mr. Belopolsky's table. The first column contains the heliocentric latitude, b; the second, the observed rotation angle, ξ_o; the third the difference $\xi_c - \xi_o$ where ξ_c is computed from the formula $\xi_c = 8^\circ.548 + 5^\circ.798 \cos b$; the fourth column, the difference $14^\circ.27 - \xi_o$.

b	ξ_o	$\xi_c - \xi_o$	$14^\circ.27 - \xi_o$	b	ξ_o	$\xi_c - \xi_o$	$14^\circ.27 - \xi_o$
	°	°	°		°	°	°
+ 11	13.90	+ 0.34	+ 0.37	− 25	14.35	− 0.55	− 0.08
+ 12	14.07	+ 0.15	+ 0.20	− 25	13.22	+ 0.58	+ 1.05
+ 18	13.49	+ 0.57	+ 0.78	+ 25	13.26	+ 0.54	+ 1.01
+ 18	14.55	− 0.49	− 0.28	+ 25	13.48	+ 0.32	+ 0.79
+ 19	14.25	+ 0.22	− 0.02	+ 25	13.95	− 0.15	+ 0.32
+ 19	13.55	+ 0.48	+ 0.72	+ 26	14.12	− 0.36	+ 0.15
+ 20	13.75	+ 0.25	+ 0.52	+ 26	13.17	+ 0.59	+ 1.10
+ 21	32.01	+ 1.95	+ 2.26	+ 26	13.53	+ 0.23	+ 0.74
− 21	12.78	+ 1.18	+ 1.49	+ 27	13.11	+ 0.63	+ 1.16
+ 21	14.70	− 0.74	− 0.43	+ 27	13.70	+ 0.01	+ 0.57
+ 22	13.97	− 0.05	+ 0.30	+ 28	13.39	+ 0.28	+ 0.88
− 22	13.60	+ 0.32	+ 0.67	+ 28	13.76	− 0.09	+ 0.52
+ 22	14.29	− 0.37	− 0.02	+ 28	14.19	− 0.52	+ 0.08
+ 22	13.55	+ 0.37	+ 0.72	+ 28	13.19	+ 0.48	+ 1.08
− 23	13.65	+ 0.23	+ 0.62	+ 28	13.85	− 0.18	+ 0.42
− 23	(15.70)	(− 1.81)	(− 1.43)	+ 28	13.78	− 0.11	+ 0.49
+ 23	13.58	+ 0.30	+ 0.69	+ 30	13.61	− 0.04	+ 0.66
+ 24	14.13	− 0.28	+ 0.14	+ 31	13.89	− 0.37	+ 0.38
− 24	13.70	+ 0.15	+ 0.57	+ 31	13.75	− 0.23	+ 0.52
+ 24	13.74	+ 0.11	+ 0.53	+ 33	13.91	− 0.52	+ 0.36
+ 24	14.00	− 0.15	+ 0.27	+ 35	13.62	− 0.32	+ 0.65

Let us now bunch these 42 differences in 5 groups of 8 or 9 observations each. The following table will then contain in successive columns the mean heliocentric latitude of the group; the mean of the difference $\xi_c - \xi_o$ for each group. The differences of these from the mean of all the observations; the mean of the difference $14^\circ.27 - \xi_o$ for each group; and finally, the deviations of these from the mean of all the observations. The figures enclosed in brackets in the second row are from the last values of the second group, which Mr. Belopolsky indicates as doubtful.

Mean hel. lat.	$\xi_c - \xi_o$	$(\xi_c - \xi_o) - 0^\circ.11$	$14^\circ.27 - \xi_o$	$(14^\circ.27 - \xi_o) - 0^\circ.56$
17	+ 0.38	+ 0.27	+ 0.57	+ 0.01
22	+ 0.13 (− 0.11)	+ 0.02	+ 0.48 (+ 0.24)	− 0.08
24	+ 0.11	0.00	+ 0.55	− 0.01
27	+ 0.07	− 0.04	+ 0.61	+ 0.05
31	− 0.16	+ 0.27	+ 0.52	+ 0.01
	+ 0.11		+ 0.56	

Now the deviations of the means for the different zones given in the third column indicate a distinct systematic error whose size and sign depend upon the numerical constants of the formula, showing that the observations are not represented by the formula. A glance at the fifth column, on the other hand, shows that on diminishing the value 14°.27 by the constant 0°.56, the observations in the zone between 11° and 35° latitude are perfectly represented. If one cares to draw any conclusion from these observations, it can only be that between Mr. Belopolsky's results and my own there is a constant difference, that his observations are perfectly represented by a constant rotation angle, and that they do not obey the rotation-law derived from the observation of spots.

Finally, I may call attention to a certain misconception of my work which appears to underlie the remarks of Mr. Belopolsky. The purpose of my investigation was to learn whether the faculæ have a rotation angle whose value is constant in this sense, viz., that the coincidences between computed and observed positions, extending over a long interval of time, are not merely accidental. The existence of such a value demands, in the first place, that the conditions in the interior of the Sun, necessary for the formation of the faculæ, should remain more or less constant for a long time. It is not, however, necessary that the faculæ themselves, which alone are available for observation, and which are a surface phenomenon, should during any short interval be independent of the general drift of the surface. For the purpose of illustration let me take an example from the physics of the Earth. The average absolute motion of the eruptive matter from any volcano is determined by the prevailing air currents of that locality, and is therefore, different in different parts of the Earth's surface, while the angular velocity of the center of eruption remains the same. If, however, one could observe at long intervals the eruptions of the same volcano he would, by a combination of these, obtain the true and constant rotation period of the Earth, from which would be eliminated all influence of atmospheric motion.

ON THE ROTATION OF THE SUN AS MEASURED BY THE POSITION OF FACULAE.*

A. BELOPOLSKY.

Greater attention has been paid my article on the rotation of the Sun from the positions of faculæ† than I expected, for I had

* *Astronomische Nachrichten*, No. 3158. † *Memorie degli spett. Ital.*, vol. XXI.

merely designed to point out that the study of the position of faculæ is of the highest importance, and that the comprehensive work of Wilsing had not yet settled the question.

Since the publication of the article, I have received letters from two distinguished investigators of the Sun-spots, Spörer and Riccò, and, in No. 3153 of the *Astronomische Nachrichten*, another paper from Wilsing appears with a criticism of my results.

The first two observers wholly agree with my conclusions as to the meaning of the signs of the differences between the angular velocities of faculæ as observed at Pulkowa and at Potsdam. Professor Spörer, in addition, sends me a series of values of the angular velocity from the determinations at Potsdam, which stand in entire accord with mine.

The paper of Wilsing's, however, is directed against my conclusions and I beg leave therefore to give it a little closer attention.

In the first place I must repeat what I have already said in my communication, that the merely numerical values of the angular velocities which I obtained are too small to lay great stress upon. At the most one can take into consideration only the sign of the differences between these and other angular velocities. Wilsing, on the contrary, regards them as reliable, and draws conclusions therefrom which in my opinion do not perhaps harmonize entirely with his own views.

He overlooks, moreover, the fact that in my article I give a column (the fifth) in which the numbers can be regarded as the values of the angular velocities, and yet in this case the values play no unimportant part. A consideration of this column shows that the faculæ which I have examined lie, not in the great zone 11° — 35°, but only in the zone 23° — 35° heliographic latitude. To find a law which is satisfied by the angular velocities within a zone of 12°, is surely not easily done even by the positions of spots. As an example, I give a series of angular velocities as obtained from the spots. It is to be remembered that a setting can be made with far greater accuracy on a spot than on a facula. Moreover the observations on the spots are separated from one another at least four days, and from that up to thirty-two days, while my observations of the faculæ are only about two days apart. And yet in the following table, the law of the decrease in rotation with the latitude is seen only with difficulty.

1875 (*Sporer, Publicationen zu Potsdam, vol. II*).

t	Latitude	ξ	t	Latitude	ξ
32d	18°	14°.22	8d	9°	14°.19
5	16	14 .04	8	8	14 .25
9	15	14 .28	10	7	14 .22
7	13	14 .04	10	7	14 .18
5	11	14 .17	9	6	14 .19
9	10	13 .94	4	4	14 .19
6	9	14 .61			

Whence we obtain as mean values:

Latitude	ξ
16°	14°.18
10	14 .19
7	14 .22
5	14 .19

All the less, then, can faculæ throw any light upon the law.

My tabulation of the angular velocities of faculæ and spots which appeared at the end of my communication was merely to show that upon the whole there was no contradiction between them.

The conclusion which is drawn from Wilsing's article and with which I also agree, points to an obvious and, as regards sign, a constant, difference between his determinations and those of mine, such that

$$W - B = + 0°.56.$$

The groups of faculæ which Wilsing employed in his investigations in 1884 lay in the zone between 6° and 15°, or, at the utmost, between 6° and 18° as can be seen from an inspection of the values which he gave. My faculæ, as already noted, lie chiefly in the zone between 23° and 35°. One can easily see, therefore, that the former must rotate faster than the latter. (The spots in the zone 6°-18° rotate daily about 0°.6 faster than those in the zone 23°-35°.)

When we remember what a host of spot-observations forms the basis of the law of rotation already known, we must expect to have a still greater number of faculæ positions for the foundation of a law of rotation for the latter.

It would be very desirable to prepare further determinations of positions of faculæ with reference to the rotation of the Sun, in order to settle this important question; each facula, however, would have to be followed up without any definite hypothesis for the identification of the groups which had been observed after a long interval.

PULKOWA, February, 1893.

ASRTO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to last page for information in regard to illustrations, reprint copies, etc.

The Congress of Mathematics, Astronomy and Astro-Physics.—In the extensive series of international Congresses now being held in connection with the Columbian Exposition, the Congress of Mathematics, Astronomy and Astro-Physics will occupy a prominent place. Its sessions will begin on Monday, August 21, 1893, in the Memorial Art Institute, Michigan Avenue, foot of Adams St., Chicago.

While it is still too early to announce the definite program of the Congress, we are able to append a partial list of the papers to be read in the Section of Astro-Physics:

Professor H. A. Rowland, Johns Hopkins University. "The Solar Spectrum."

Professor S. P. Langley, Smithsonian Institution. On Bolometric Investigations.

Professor E. C. Pickering, Harvard College Observatory. "The Constitution of the Stars."

Professors Kayser and Runge, Technische Hochschule, Hannover, Germany. "The Spectra of the Elements."

M. H. Faye, Paris. "Theory of the Sun."

Professor F. H. Bigelow, U. S. Weather Bureau. "Magnetic Fields of the Sun."

Mr. E. Walter Maunder, Royal Observatory, Greenwich. "The Classification of Stellar Spectra."

Dr. H. Ebert, Erlangen, Germany. "Electro-Magnetic Theory of the Corona."

Rev. Walter Sidgreaves, S. J., Stonyhurst Observatory, Lancashire, England. "The Stonyhurst Solar Investigations."

Rev. F. Denza, Observatory of the Vatican, Rome. "Astro-Photographic Investigations."

Professor W. W. Campbell, Lick Observatory. "The Wolf-Rayet Stars."

Professor Fitzgerald, Dublin. "Terrestrial Magnetism."

Dr. A. Brester, Jz., Delft, Holland. "Theory of the Sun."

Herr Victor Schumann, Leipzig, Germany. "Photographic Investigations in the extreme Ultra-Violet."

Messrs. L. E. Jewell and Joseph S. Ames, Johns Hopkins University. (1). "Constitution of the Oxygen Absorption Bands." (2). "Variation in Metallic Lines with amount of Metal in the Arc." (3). "An Absolute Photometric Scale for Spectrum Lines."

The above list, while incomplete, will serve to indicate the nature of the program. For the Sections of Mathematics and Astronomy, a large number of papers have been promised. Among foreign astro-physicists already in this country or expected in time for the Congress may be mentioned Professor P. Tacchini, Dr. Max Wolf, Herr Eugen von Gothard, Professor James Dewar, Mr. A. Cowper Ranyard, Professor W. N. Hartley and Dr. H. Ebert. The discussions following the reading of papers will be stenographically recorded, and published in the volume of proceedings.

A cordial invitation to attend the sessions of the Congress is extended to everyone interested. Further information may be obtained by addressing George E. Hale, Secretary of the Local Committee, Kenwood Observatory, Chicago.

Astronomical Exhibits at the Columbian Exposition.*

Exhibit of the U. S. Naval Observatory, (east of the United States Government Building) in charge of Lieut. A. G. Winterhalter, U. S. N.

Small Observatory with 5-inch equatorial refractor.
40-foot photoheliograph.
3-inch transit, clocks, large collection of chronometers.
Publications of the U. S. Naval Observatory.
Photographs, drawings, etc.

Manufactures and Liberal Arts Building, North Gallery.

WARNER & SWASEY.

40-inch Yerkes telescope.
12-inch equatorial telescope.
6-inch equatorial telescope.
4½-inch equatorial telescope.
4 inch telescope on tripod.

Chronograph, photographs of the Lick telescope, drawings of Washington 26-inch equatorial, dome and elevating floor. Photographs of Moon taken with the Lick telescope.

J. A. BRASHEAR.

Stellar spectroscope for the 40-inch Yerkes telescope.
2 standard spectroscopes.
6½-inch equatorial reflector.
Small equatorial mounting and heliostat.
18-inch objective and smaller objectives.
Plane and parabolic specula, gratings, micrometers, helioscopes, prisms, etc.
Photographs of Lick and Princeton spectroscopes.

GEORGE N. SAEGMULLER.

9-inch equatorial telescope, Clacey objective with photographic corrector.
4-inch equatorial telescope.
4-inch steel meridian circle.
2-inch transit.
3-inch transit.
2 chronographs, astronomical clocks.
Photographs of transits and other instruments.

PROFESSOR GEORGE W. HOUGH.

Printing chronograph.

BRITISH ASTRONOMICAL ASSOCIATION.

Exhibit of publications, drawings, etc.

KENWOOD OBSERVATORY.

Photographs of Observatory, instruments, solar prominences, faculæ and ultra-violet spectrum of chromosphere.

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* The following list of exhibits is not complete, but even in its present form it may be of some service to visitors at the Exposition.

PROFESSOR JAMES E. KEELER.

Drawings of Jupiter and Saturn.

OBSERVATORY OF THE VATICAN.

Set of publications.

PROFESSOR P. TACCHINI.

21 volumes Memorie della Societá degli Spettroscopisti Italiani.
23 volumes Annali dell 'Ufficio Meteorologio E Geodinamico Italiano.
13 volumes Rivista Meteorico Agraria.
26 volumes Bollettino Meteorico Geornalier.

East Gallery.

VION FRÈRES (PARIS).

Small refractors and reflectors.

PELLIN (PARIS).

Darsonval spectro-photometer.
Large Silbermann heliostat.

TEIGNE ET MOREAU (PARIS).

Small equatorial telescope.

WERLEIN (PARIS).

Glass, quartz, fluorspar, etc.

PROFESSOR LIPPMANN (PARIS).

Photographs of spectra and other objects in colors.

West Gallery.

GERMAN EDUCATIONAL EXHIBIT.

Kirchhoff's original spectroscope.

Jena optical glass, spectro-photometer, mercury pumps, (Gerhardt, Bonn).

Set of mathematical models, (Brill). Guericke's original air-pump.

Computing machines, Geissler pumps, scientific books,

Original magnetic apparatus of Gauss and Weber, Diamagnetometer, Photographs of magnetic instruments (from the Gauss Erd-Magnetisches Observatorium, Goettingen, Germany).

Photographs of the photographic equatorial, stellar spectrograph and magnetic instruments; copies of magnetic curves, Astrophysikalische Observatorium, Potsdam.

ROYAL ASTRONOMICAL SOCIETY.

14 photographs of stars, nebulæ, etc., by Dr. Isaac Roberts.

2 large photographs of composite drawing made from all the negatives of the total solar eclipse of 1882. Photographs of the eclipses of 1870, 1871, 1882, 1883 and 1886. Photographs of the compared spectra of the Sun and meteorites from D to K, by Sergeant Kearney, R. E. Series of nine photographs of the Great Sunspot of February 1892. Spectra of the Sun, Arcturus and Nova Aurigæ. Thirteen photographs of stellar spectra.

Photographs from the Royal Observatory, Greenwich, including chart plates of the Pleiades, catalogue plate with trail for orientation, ω^2 Cygni (seven exposures), photographs of the Sun, etc.

Photograph of the Great Comet of 1882, by Dr. David Gill.

Capt. Abney's photograph of the Infra-red solar spectrum.

DR. A. A. COMMON.

Parabolic speculum of 5-feet aperture (unsilvered).

THE EARL OF ROSSE.

4 drawings of the Milky Way, by Dr. Otto Boeddicker.

West Gallery, Third Floor.

SCHMIDT UND HAENSCH.

Large spectro-photometer.

FUESS.

Heliostat.

South Gallery.

HARVARD COLLEGE OBSERVATORY.

Several hundred photographs of instruments and observatories in Cambridge, Colorado, California, Chili and Peru, stellar spectra, double stars, star trails, comets, clusters, nebulæ, the solar corona, Moon, Jupiter and satellites, Mars, Saturn and satellites, Uranus and three satellites, Neptune and satellite, etc., etc.

AMHERST COLLEGE.

Pneumatic commutator sheet used in operating automatic eclipse instruments. Photographs of automatic eclipse instrument, 40-foot telescope, and other instruments used at the African eclipse of 1889. Photographs of the transit of Venus photoheliograph, and enlarged photograph of Sun with Venus in transit. Photographs of the Amherst Observatory, equatorial and transit instrument.

UNIVERSITY OF THE CITY OF NEW YORK.

Photographs of stellar spectra, etc., by Dr. Henry Draper.

Bronze bust of Dr. Henry Draper.

Print from photograph of 40-foot telescope at Slough, taken by Sir John Herschel in 1839. Original daguerreotype of solar spectrum, taken by John W. Draper in 1842. Oldest existing daguerreotype, taken by John W. Draper in 1840.

JOHNS HOPKINS UNIVERSITY.

Rowland and Rutherfurd gratings. Photographs of solar and metallic spectra by Professor Rowland.

PRINCETON UNIVERSITY.

Photographs of the Halsted Observatory and Students' Observatory.

The Rittenhow Orrery (1770).

CARLETON COLLEGE.

Drawings of Venus, Jupiter and Holmes' Comet, by Dr. H. C. Wilson.

Photographs of the Observatory, Sun, Moon and Orion Nebula.

DE PAUW UNIVERSITY.

Dr. Chandler's original 4-inch almucantar.

Photographs of the Observatory, equatorial, meridian circle, and chronograph.

BELOIT COLLEGE.

Photographs of the Observatory and equatorial.

YALE UNIVERSITY.

Photographs of the Observatory and heliometer.

LEHIGH UNIVERSITY.

Photographs of the Observatory, equatorial and zenith telescope.

UNIVERSITY OF WISCONSIN.

Photographs of Observatory, equatorial, and dome and equatorial of Students' Observatory.

UNIVERSITY OF MICHIGAN.

Photographs of Observatory, equatorial, meridian circle and Practice Observatory.

MOUNT HOLYOKE COLLEGE.

Photographs of Observatory, equatorial and transit instrument.

SMITH COLLEGE.

Photographs of Observatory and equatorial.

VASSAR COLLEGE.

Photograph of Observatory.

CLARK UNIVERSITY.

Photographs of Michelson's interferential refractometer, mathematical models and physical instruments.

WESTERN UNIVERSITY OF PENNSYLVANIA.

Langley's original bolometer, photographs of infra-red solar spectrum, equatorial telescope, stellar spectroscope, transit instrument, galvanometer and switchboard. Mathematical models by Professor R. T. Stewart.

Main Isle (Swiss Exhibit).

LA SOCIÉTÉ GENEVOISE.

Spectroscopes, spectrometers, heliostats, dividing engines, transits, etc.

Electricity Building, East Gallery.

MERZ (MUNICH).

9 objectives, 10-inch aperture and smaller.
2 equatorial telescopes.

VOIGTLÄNDER UND SOHN.

Photographic objectives.

SCHMIDT UND HAENSCH.

Universal spectroscope, spectro-photometer, polarizing apparatus, prisms, etc.

STEINHEIL (MUNICH).

Large spectrograph, spectroscope, spectrometer, small refracting telescope, prisms and telescope objectives.

DR. STEEG AND REUTER (BAD HOMBURG).

Glass, quartz and rock salt prisms, etc.

KRUSS (HAMBURG).

Large automatic 6-prism spectroscope,
Small automatic 6-prism spectroscope,
Universal spectroscope for qualitative and quantitative analysis.

BERNHARD HALLE (STEGLITZ).

Iceland spar polarizing prisms, prisms and plates of rock salt, alu m, tourma line, etc.

ZEISS (JENA).

Abbe spectrometer, with illuminating and heating apparatus, comparator for measuring spectra, photographic objectives, etc.

SCHOTT UND GENOSSEN (JENA).

Large collection of optical glass, including a pair of 23-inch telescope discs.

MAX KOHL (CHEMNITZ, SAXONY).

Large induction coil and other physical apparatus.

S. REIFLER (MUNICH).

Astronomical clocks.

Agricultural Building—N. E. Corner.

CAPE COLONY EXHIBIT.

Dr. David Gill's photographs of stars, nebulæ, etc.

California State Building.

LICK OBSERVATORY.

Glass transparencies from photographs of the Milky Way, Moon, planets, comets, Observatory, instruments, etc.

The Total Eclipse of April 16.—In the *Comptes rendus* for May 15, M. Deslandres gives the results of his observations of the total eclipse in Africa. Twenty-two photographs of the corona were obtained with different objectives, plates and exposures. Some of the negatives show streamers equal in length to twice the solar diameter. The general form of the corona is that characteristic of maximum spot periods. In attempting to photograph the ultra-violet portion of the coronal spectrum and to determine the velocity of rotation of the corona by displacement of the lines a spectroscope of large dispersion was used without success. An instrument of smaller dispersive power allowed the spectrum to be photographed to the limit of the ordinary solar spectrum, and fifteen bright lines were obtained. In the determination of the rotation of the corona the spectra of opposite points of the corona, situated in the equatorial plane, and at a distance of two-thirds the solar diameter from the limb, were photographed edge to edge. The spectra showed a slight displacement, corresponding to a difference of velocity of from 5 km to 7.5 km. M. Deslandres concludes that the corona closely follows the photosphere in its motion. No dark lines were found in the coronal spectrum. The light of the corona was composed simply of bright lines and a strong continuous spectrum.

Report of the O-Gyalla Observatory for 1892.—We have received from Dr. Nicolaus von Konkoly the "Berichte aus dem astrophysikalischen Observatorium in O-Gyalla (1892)," a reprint from the "Berichte" of the Hungarian Academy. The number of Sun-spots in 1892 was determined from drawings made on 157 days, and a "relative number" (Wolf) of 53.63 resulted. Observations of meteors and meteor radiants were made in July and August at O-Gyalla, Pressburg and Budapest, and on certain occasions simultaneous observations were made at two stations. In all 264 meteors were recorded. The spectroscopic observations included those of Nova Aurigæ, Comet Swift, Comet Holmes and β Orionis. The spectrum of Comet Holmes, as observed on November 18, was so feeble that the colors of the faint continuous spectrum could be seen only with a very wide slit. During the year a large collection of meteorological instruments was added to the equipment of the Observatory.

Photography of the Spectrum of Comet Swift.—In Eder's "Jahrbuch," 1893, Herr Eugen von Gothard describes his photograph of the spectrum of Swift's

Comet, made in three days (in April, 1892) with a total exposure of four hours. For purposes of comparison the Bunsen burner spectrum was photographed on the same plate. The spectra were found to be identical as far as the fourth band (λ 473 — λ 467), but from there onward, appear new unknown lines and bands, (which are wanting in the comparison spectrum) with faint carburetted hydrogen bands (λ 389 — λ 387). These latter are not identical with, but quite similar to those which appear so characteristically in the carburetted hydrogen spectrum. It would thus seem that the compound of carburetted hydrogen existing in comets differs in composition from our coal gas, and probably exists under physical conditions different from those occurring in the Bunsen flame.

Spectroscopic Determination of Stellar Rotation.

To the Editor of Astro-Physics:

DEAR SIR: The widening of the lines in the spectrum of a star is generally ascribed to high temperature; and, no doubt, most of it is due to this cause; but must not a certain part be due to axial rotation? To make my meaning clear, suppose a distant star, situated in the plane of our Sun's equator, and suppose there to be an observer in this star, examining the light of our Sun with a good spectroscope; then one edge of the disc would be advancing towards him with a velocity of a little over one mile per second, while the other edge would be retreating with the same velocity. Other portions of the disc would be moving with intermediate velocities; so that the total effect would be to broaden out a fine line into a band, whose width would correspond to the algebraic difference of these velocities, viz., two miles a second. A similar effect ought to be visible to us, when examining the spectrum of a star, except in the improbable case of our being situated nearly in the prolongation of the stellar axis. In general, this effect would be mixed up with the widening produced by high temperature, so that it would be impossible, or nearly so, to separate the two. It seems to me, however, that even in this case something might be done with a telescope of large aperture and a spectroscope of considerable dispersive power, by the aid of the considerations that the broadening due to rotation ought to affect all lines equally, and that the distribution of intensities in different parts of the band ought to follow a uniform and easily deducible law. But in the case of variable stars, like Algol, where the diminution of light is supposed to be due to the interposition of a dark companion, it seems to me that there ought to be a spectroscopic difference between the light at the commencement of the minimum phase, and that of the end, inasmuch as different portions of the edge would be obscured. In fact, during the progress of the partial eclipse, there should be a shift in position of the lines; and although this shift is probably very small, it ought to be detected by a powerful instrument.

J. R. HOLT.

A new Method of Stellar Photometry by Lagrange and Stroobant.—The idea is to place a small incandescent electric lamp, near the objective, but outside the tube, of an ordinary refractor. Near the eyepiece, but in the side of the tube, is placed a short-focus lens. By means of two plane metallic mirrors, one in front of this lens and one behind it, an image of the small lamp is thrown into the field of the refractor.

To compare the brightness of the lamp with that of the star the following arrangement is used. An iris diaphragm is placed in front of the lamp, *i. e.*, on the side next the observer. In addition to this a pair of sliding colored glass wedges is arranged between the lamp and the iris diaphragm. It still remains to regu-

late the current in the lamp or to correct for its variations. The authors choose the latter alternative and keep a photographic record of the voltage of the lamp, from which, knowing the intensity of the light as a function of the voltage, they correct for any change in their standard.

A lamp of this kind is so very sensitive to any change in the E.M.F. of the battery that the method can hardly be said to inspire confidence.—[*Bull. Acad. roy. Belgique,* 3rd ser., *t.* 23, pp. 811-827. Reprinted in *Jour. de Physique* for April, 1893.]

Radiation of Rarified Gases, by K. Angström. This is a piece of work whose description covers thirty-eight pages in the current number of *Wiedemann's Annalen.* In it many large questions are started regarding the nature of the phenomena observed in a Geissler tube. The paper being confessedly preliminary and incomplete, one is not surprised on laying it down to find many of these questions almost untouched. The author measured, with a not very sensitive bolometer, the total radiation of a Geissler tube. To excite the tube he used either a tremendous storage battery of 800 cells interrupted by a tuning fork or the secondary of an induction coil. Currents were measured in amperes, not merely scale divisions, and the radiation reduced to gram-calories.

Four gases were examined, viz., oxygen, hydrogen, nitrogen and carbon-monoxide. Special attention was given to obtain the gases in a pure state. The oxygen and hydrogen were prepared electrolytically. Most of the measures were made on tubes in which the pressures ranged from 0.12 to 2.66 millimeters of mercury.

Under these circumstances, it was found, among other things, that—

1. For any single gas, under constant pressure, the radiation is proportional to the exciting current.

2. In any single gas, under constant pressure, the *ratio* of luminous to non-luminous radiation does not vary with the current.

[Here "non-luminous" rays are defined as those which do not pass through an alum solution. "Luminous" rays are those which do.]

3. The ratio between the energy which the tube *radiates* and that which the current developes in the tube (Joule effect) increases as the pressure of the gas decreases.

4. The optical efficiency of this radiant energy, *i. e.*, the proportion of it which is luminous, depends upon the nature of the gas. In the case of nitrogen, under low pressure, as much as 90 per cent of this radiation passes through the alum solution.

5. The total radiation from any tube is to be looked upon as a function, *primarily*, of the chemical constitution of the gas; and, *secondarily* only, as a function of the electric discharge. Molecular structure of the gas is the all-important factor.—[*Wied. Ann.,* Bd. 48, pp. 493-530 (1893).]

Flame Spectra at High Temperatures.—*Part 1. Oxyhydrogen Blowpipe Spectra.*—Brewster, in 1842, first examined the spectra of salts with a flame of oxygen and coal-gas (Proc. Roy. Soc., Edin., vi., p. 145.)

Professor Norman Lockyer has given us maps of twenty-two metallic spectra at the temperature of the oxygen and coal-gas flame. The region observed lies between λ 7000 and 4000.

Preparatory to undertaking the study of spectroscopic phenomena connected with the Bessemer "blow" and the manufacture of steel generally, I have care-

fully observed the spectra of metals and metallic oxides obtained by submitting the substances to the oxyhydrogen flame.

Method of Investigation.—The method of obtaining spectra with flames at high temperatures is the following. Hydrogen proceeding from a large lead generator is burnt in a blowpipe with compressed oxygen. The blowpipe measures 3 in. in length by ⅜ in. external diameter. The substances examined are supported in the flame on small plates of kyanite about 2 in. in length, one-twentieth in. in thickness, and ¼ in. in width. This mineral, which is found in masses in Co. Donegal, contains 96 per cent of aluminium silicate, and is practically infusible. The spectra were all photographed by me with the instrument employed by me on former occasions for photographing ultra-violet spectra, illustrations of which were published in the Chem. Soc. Journ., XLI., p. 91, 1882. The dispersion of the instrument was that of one quartz prism of 60°.

Isochromatic plates developed with hydroquinone were largely used. Various dyes for sensitising and all kinds of developing substances were tried. The spectra were measured with an ivory scale divided into hundredths of an inch, and directly applied to the photographs, the division 20 on the scale being made to coincide with the yellow sodium line which appears on every photograph. It was found convenient to record the measurements on a gelatine-bromide paper print taken from an enlarged negative. Sometimes, for more careful and minute reference, it was found convenient to make an enlargement of the spectrum with the scale in position, but accurate measurements cannot be made in this way. It is necessary to use a low magnifying power and cross-wires in the eye-piece.

For the identification of the lines already known nothing more complicated is required, but to measure new lines and bands it was considered desirable to make use of a micrometer and microscope; the screw of the micrometer was cut with 100 threads to the inch, and the magnifying power generally used was 10 diameters.

Characters and Extent of the Spectra Observed.—Just as in the ordinary use of the spectroscope we must be prepared to see the lines of sodium, and in hydrocarbon flames the bands of carbon, so in these spectra the sodium lines and the strongest lines belonging to the emission spectrum of water vapor are also always present.

In addition, the kyanite yields the red line of lithium, which is no inconvenience, but a positive advantage, serving, as it does, to indicate where the spectra commence.

A large majority of the metals and their compounds all terminate somewhere about the strongest series of water vapor lines. Typical non-metallic spectra are sulphur, selenium, and tellurium; the first yields a continuous spectrum with a series of beautiful fluted bands, the second a series of fine bands occurring at closer intervals, and the third is characterised by bands still closer together, and nearer the more refrangible termination of which four lines occurring in Hartley and Adeney's spark spectrum of tellurium are visible. Increase in atomic mass causes shorter periods of recurrence of bands. In line spectra it is the reverse; increase in atomic mass causes greater periods in the recurrence of lines. Charcoal and carbon monoxide yield chiefly continuous spectra; the latter, however, exhibits only carbon lines. The hydrocarbons yield the well-known spectrum of carbon bands with also those attributed to cyanogen. Of metallic elements, nickel, chromium and cobalt yield purely line spectra; antimony, bismuth, silver, tin, lead, and gold beautiful banded spectra (spectra of the first order) accompanied by some few lines. These spectra are finer than those of selenium and tellurium.

Iron and copper exhibit lines and, less prominently, bands. Manganese has a beautiful series of bands and a group of three very closely adjacent lines. Aluminium gives a fine continuous spectrum with three lines, origin uncertain, zinc a continuous spectrum without lines, and cadmium a spectrum consisting of one single line only, λ 3260.2.

Of compounds, chromic trioxide yields a continuous spectrum with six lines belonging to the metal, copper oxide a fine banded spectrum with two lines of the metal, magnesium sulphate gives a spectrum of magnesium oxide consisting of broad degraded bands composed of closely adjacent fine lines and one line belonging to the metal, λ 2852.

The sulphates of calcium, strontium and barium give both bands of the oxides and lines of the elements. Phosphorus pentoxide yields a continuous spectrum with one peculiar line, seen also in the spectrum of arsenic.

The chlorides of the alkalis give also lines of the elements with a more or less continuous spectrum, which, it is believed, is due to the metal in each case. Lithium chloride gives no continuous spectrum.

The Volatility of Metals.—One of the most interesting facts ascertained by this investigation is the volatility of all the metals examined, except platinum, and particularly the extraordinary volatility of manganese, and, to some extent, of the infusible metal iridium. Metal believed to be pure iridium is seen to have diminished after the flame has played upon it for about two hours. (Abstract of a paper read before the Royal Society, by Professor W. N. Hartley. From the *Chemical News.*)

Photography of Sun-Spot Spectra.

PRINCETON, N. J., May 23d, 1893.

MY DEAR MR. HALE:

I take the the liberty to send you some negatives of Sun-spot spectra for reproduction, if you think it worth while, in "ASTRONOMY AND ASTRO-PHYSICS." They show very fairly the widening of lines in the spectrum, but not so well the occasional narrowing of others. In the C plate [No. 135], the little line at 6573 just below C, shows well, but C itself in this spot unfortunately was not much narrowed,—not the slightest tendency towards reversal is evident. Perhaps the best of the negatives is No. 131. I have marked on the plate the approximate position of the two lines at 5727 and 5732 which are always very much widened, and have between them two other lines, which in the spot-spectrum are generally nearly as strong, though almost invisible outside of the spot itself. 5727 and the other one close to it are Vanadium lines according to Rowland.

As you will see at once the focus is good only over about one-third the length of the spectrum, and on each of the plates one of the spectra is much better than the other two. Please pick out the best ones for printing, if you determine to use them. The plates are Cramer's isochromatic, which, as you see, can be made to work clear down to B.

Mr. Reed has succeeded in getting photographs of the reversal of both C and D_3, and even photographs of a prominence seen through these lines, though nothing very satisfactory as yet. But I see no reason why, with a little more experience, he may not soon get really good pictures of the prominences as seen through C to compare with the same seen through H and K. I think they will be found to present significant differences. I send one of his D_3 pictures; but he has so far got only one or two C negatives, and I will wait until he gets something more before sending a specimen of them.

No. 130 is taken in the second order, 131 in the third, and 135 in the first,—all with the 20,000 line grating.

Yours truly,

C. A. YOUNG.

We much regret that the small scale of the photographs and the insufficient contrast renders impossible their satisfactory reproduction. The widened lines are beautifully shown, and no doubt can remain as to the value of the photographic method for recording them.

Lunar Photography with a Visual Telescope.

NAPA COLLEGE, NAPA, CALIFORNIA, May 25, 1893.

To the Editor of Astro-Physics,

DEAR SIR: I take pleasure in sending you by mail to-day a few prints and enlargements from negatives of the Moon made with the 8-inch *visual* telescope of Napa College Observatory. These photographs, excepting that of the full Moon, bear magnifying with a lens of 1-inch focal-length very well, better in fact than almost any of the Lick Observatory pictures. I hope you may find the pictures of interest and value.

Yours very truly,

ROGER SPRAGUE.

The photographs sent by Mr. Sprague are remarkably good; in fact, when it is considered that a *visual* telescope was employed, the sharp definition is surprising. An examination of these photographs might well induce any possessor of a visual telescope to undertake astronomical photography.

Observations of Comet *b* 1893.—The announcement of the discovery of a new comet in the constellation Lynx was received at this Observatory on July 10, and on the same evening the comet was observed by Professor A. O. Leuschner and myself with the thirteen-inch equatorial. It was low in the northwest, but the sky in that direction happened to be unusually free from clouds and smoke, so that a fairly good view was obtained. The coma was round, with a strong central condensation, and shaded off without any perceptible boundary into the somewhat bright background of the sky. The tail mentioned in the announcement could not be detected, but the coma on the side opposite the Sun seemed to fade a little more gradually than elsewhere, and the beginning of the tail was probably indicated by this appearance.

With a single light prism on the large spectroscope described in the January number of ASTRONOMY AND ASTRO-PHYSICS, the spectrum was at once seen to be a beautiful example of the usual hydrocarbon type. The three bands were remarkably bright and distinct, and they were connected by a narrow continuous spectrum, due to the nucleus, which extended for some distance on both sides of the bands, and exhibited a marked increase of brightness at the points of crossing. No superposed lines could be seen, nor could any other bands be certainly detected.

The bands terminated sharply on the less refrangible side, where the brightness also seemed to be greatest. This appearance was most noticeable in the middle and brightest (green) band. On narrowing the slit the edge became so bright and sharp as to resemble a narrow, bright line, like the terminal line of the corresponding hydrocarbon fluting. The second maximum of this fluting could not, however, be recognized in the cometary band.

This observation has some interest, in view of the fact that very frequently, in cometary spectra, the maximum brightness of the bands is not found at their less refrangible edges, as it always is in the artificially produced hydrocarbon spectrum.

A direct comparison of spectra was not made, and unfavorable weather has prevented measurements or any further visual observations.

It was interesting to observe how much farther the coma could be traced with the spectroscope than in the ordinary eye-piece with the eye alone. The bright sky background which in the latter case made the coma invisible at a short distance from the nucleus, was by the spectroscope spread out into a faint continuous spectrum, which did not interfere perceptibly with the visibility of the bright hydrocarbon bands. By moving the slit slowly across the image of the comet (in declination). and noting the points at which the last traces of the bands disappeared, the diameter of the coma was found to be about 9′.5, or nearly twice what it appeared to be in the eye-piece of the telescope.

Attempts were made to photograph the spectrum on July 12 and 14, through a very smoky atmosphere, and naturally without success.

This evening (July 19) we succeeded in obtaining a photograph of the spectrum of the comet, using a single prism on the large spectroscope. The exposure was two hours, but the last hour certainly counted for very little. A preliminary exposure of one minute was made on the Moon, with half of the slit covered, and the cometary spectrum was then photographed with the other half, the lunar spectrum serving to identify the lines in the spectrum of the comet when the plate was developed. For the Moon the slit-width was 0.001 inch, and for the comet 0.01 inch.

Two strong bands appeared upon the plate; one the carbon fluting at λ 472, which is the most refrangible of the three bands seen with the eye, and the other in the ultra violet, above the *K* line On account of the large slit-width the wave-lengths could be only approximately determined. The band at λ 472 was not sharply defined, and looked more like a hazy band than like a fluting. The other was sharply terminated by a line on the less refrangible side, at λ 388, and shaded away somewhat rapidly on the other. Between these two bands were perhaps some others, but they were too faint to be distinguished certainly from blotches on the film. The continuous spectrum of the nucleus was not seen on the plate, perhaps on account of the difficulty of telling when the nucleus was in the slit, in guiding the telescope.

It is easy to identify the ultra-violet band with the carbon band, or rather group of lines, photographed by Dr. Huggins in the spectrum of comet *b* 1881. Traces of doubling were even visible, corresponding to the two strongest lines on Dr. Huggins' photograph. The two groups of lines shown in Dr. Huggins' drawing in *Proc. Royal Soc.*, Vol. XXXIII, plate I., do not appear in my photograph.

July 20. The sky was clear last night and further observations were made. The nucleus was brighter than before, and the tail was conspicuous.

With the spectroscope, arranged as on July 10, the spectrum of the comet was carefully observed with special reference to the distribution of light in the bands. The lower edges still seemed to be the places of maximum brightness, but the light did not fall off rapidly toward the violet. Comparison with the flame of an alcohol lamp showed a coincidence of the cometary bands with the flutings of hydrocarbon which could be determined with much exactness in the case of the brightest band, and less satisfactorily in that of the others.

Both Professor Leuschner and I were almost certain that we could see the second maximum of the hydrocarbon fluting in the brightest cometary band, and we independently noted the two star-like points where the continuous spectrum of the nucleus was crossed by the terminal lines of the first and second maxima.

Allegheny Observatory, JAMES E. KEELER.
July 21, 1893.

The Spectrum of Comet *b* 1893 (Rordame).—The spectrum of this comet has been observed here both visually and photographically, and a large number of new bright lines have been detected.

VISUAL OBSERVATIONS.

The yellow, green and blue bands appear with their usual intensities, but their less refrangible edges seem to be completely resolvable into bright lines. Wave-lengths were determined for two lines in the yellow band, three in the green and one in the blue; and several other ill-defined lines were seen in the yellow and blue bands. A red band at w. l. 601 and violet bands at w. l. 434 and w. l. 421 are easily visible. The wave-lengths obtained are given in the following table. The fourth column contains Kayser and Runge's wave-lengths of the edges of the corresponding carbon bands.

July 11.	July 12.	July 17.	Carbon bands.	Description of bright lines and bands.
600	601		619—595	Maximum of red band broad, faint.
562	—	—	—	Red edge of yellow band.
—	—	5633	5635	Very faint line terminating yellow band.
—	—	558	5585	Bright line in yellow band.
5162.1	5161.8	5163.9	5165.3	Very bright line terminating green band.
5124	5127	5128	5129	Very bright line in green band.
—	—	509	—	Very bright line in green band.
4734	—	—	4737	Red edge of blue band.
—	—	4734	4737	Bright line terminating blue band.
—	434	—	—	Bright region in continuous spectrum, faint.
—	421	—	—	Bright region in continuous spectrum, faint.

PHOTOGRAPHIC OBSERVATIONS.

Two photographs of the region w. l. 487-387 were obtained. They show five lines in the less refrangible side of the blue band. The two violet bands observed visually at w. l. 434 and 421 are shown to consist of five and two lines respectively. The results for these plates are given below; and likewise, in the last column, the wave-lengths of the corresponding bands and lines of carbon and cyanogen as given by Kayser and Runge.

July 13.	July 16.	Carbon.	Description of bright lines.
4736.1	4736.3	4737.2	Very bright line, the head of blue band group.
4716.7	4715.2	4715.3	Very bright line, in the blue band group.
4698.1	4696.0	4697.6	Very bright line in the blue band group.
4683.4	4683.0	4684.9	Brightest line, in the blue band group.
4674.8	4675.4		Apparently a very bright line, in the blue band group, but not well separated from 4683.
455	—	—	Exceedingly faint, possibly a defect in film.
452	—	—	Exceedingly faint, possibly a defect in film.
449	—	—	Exceedingly faint, possibly a defect in film.
4366.3	4366.1	(4365.0?)	Very bright line.
4350.3	4349	—	Very faint line.
4333.9	4335.8	—	Faint line.
4313.2	4312.7	—	Very bright line.
4298.7	4298.0	—	Very bright line.
4253	426	—	Very faint line.
4235	4234	—	Very faint line.
		Cyanogen	
4214.3	4214.2	4216.1	Very bright line.
4196.7	4195.8	4197.2	Bright lines.
4178	—	4180.7	Very faint line, uncertain.
4126	—	4128.1	Faint line.
4098.0	4097.8	4099.2	Bright line.
4071.8	4073.5	4073.7	Bright line probably double, at 4075 and 4069.
4052.4	4052.2	4053.3	Bright line.
4043.9	4042.3	—	Bright line.

July 13.	July 16.	Cyanogen.	Description of bright lines.
4017.1	4021.4	—	Bright line.
4011.2	—	—	Faint line.
3988	3988	—	Very faint line.
3881.2	3881.3	3883.5	Very bright line, probably brightest in spectrum.
3870.0	3869.9	3871.5	Bright line, broad, resembles a band, more refrangible edge faint.

The agreement of the comet spectrum with the strong bands and lines in the carbon and cyanogen spectra is perfect, within the limits of error, except that the wave-lengths for the comet are systematically less by one or two tenth-metres than Kayser and Runge's results. At first I was inclined to attribute the discordance to the large flexure of the spectroscope when the great telescope is in nearly a horizontal position. But the same discordance exists also in the visual observations, which are not affected by flexure. An explanation is probably to be found in the fact that in the various spectra we have to deal with unsymmetrical bands, rather than lines. Possibly, also, the motion of the comet to or from the Earth, is sufficient to affect the results appreciably. The region w. l. 436 — 423 does not appear to have been covered by the work of Kayser and Runge.

The 36-inch telescope presents several positive disadvantages for comet spectrum work, of which I may mention two.

The ratio of focal length to aperture, 19 : 1, is much larger than exists in small telescopes, and hence the latter would form much brighter images on the slit-plate than the former.

The guiding in photographic work with the long telescope is difficult with low and rapidly moving objects. W. W. CAMPBELL.

Spectrum of Comet *b* 1893.—The spectrum of this comet was observed at the Kenwood Observatory with the 12-inch equatorial on the evening of July 14, a single flint prism of 60° being used in the spectroscope. The three bands of the hydrocarbon spectrum were well seen, and were found by direct comparison to agree accurately in position with these bands in the alcohol flame spectrum. They were sharply defined on the less refrangible edge, and much brightened in the comet's nucleus, where they were crossed by a continuous spectrum. No other lines or bands were seen. GEORGE E. HALE.

Attempt to Photograph the Corona from Pike's Peak.—The method devised by myself for photographing the solar corona without an eclipse, and described in recent numbers of this journal, was tried on Pike's Peak during the latter part of June, but without success. Numerous fires in the forests surrounding the Peak sent up vast volumes of smoke, and the natural deep blue of the sky gave place to whiteness nearly as marked as that seen under ordinary conditions in Chicago. For this reason it is not considered that the method has been sufficiently tested by these experiments. The night "seeing" on the Peak was invariably very poor

GEORGE E. HALE.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR SEPTEMBER AND OCTOBER.

Mercury is morning planet during the first part of September, but rises too near sunrise to be visible to the naked eye. On the 20th Mercury will be at superior conjunction. Toward the end of October the planet will become visible in the evening twilight, just after sunset.

Venus is the bright "evening star" which is so noticeable in the west after sunset at this time. The motions of the Earth and Venus are so related now that Venus appears to recede very slowly from the Sun, and will not be in very favorable position for observation until the latter part of October. Venus will be in conjunction with the Moon, 30′ north, Sept. 12 at $11^h 19^m$ P. M., central time, and again, 1°49′ north, Oct. 13, $6^h 40^m$ A. M. On Oct. 12, at $8^h 39^m$ P. M. the star δ Scorpii will be seen in the same field of the telescope with Venus, the star being 13′ south of the planet.

Mars will be in conjunction with the Sun Sept. 4 and will not be visible during the following month.

Jupiter is now a very brilliant object in the morning sky. During September and October Jupiter will be in most excellent position for observation, especially during the latter half of the night. The planet is in the constellation Taurus between the Pleiades and Hyades, and is moving very slowly. It is now moving eastward, will be stationary Sept. 19, and after that will retrograde slowly. Jupiter will be in conjunction with the Moon Sept. 2 at noon, Sept. 29 at $6^h 31^m$ P. M., and again Oct. 26 at $11^h 12^m$ P. M., central time. At all of these conjunctions the Moon will pass from 4° to 5° north of Jupiter.

Saturn will be at conjunction with the Sun Oct. 8, and will therefore be invisible during the months of September and October.

Uranus will be too low in the west in the evening to be well seen. He will be in conjunction with the Moon, 2°14′ north, Sept. 14 at $12^h 55^m$ A. M. and again, 2° 24′ north, Oct. 11 at noon.

Neptune will be at quadrature, 90° west of the Sun on Sept. 5. The position is very favorable for observation especially after midnight. It is in Taurus about 14° east of Jupiter, about 2° west and 32′ south of the 5th magnitude star ι Tauri. On Sept. 15 Neptune will be at the stationary point of his apparent path among the stars and will be very nearly in the same place during the two months of September and October.

MERCURY.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5	10 11.5	+12 49	4 17 A. M.	11 11.4 A. M.	6 05 P. M.
15	11 22.5	+ 5 56	5 17 "	11 42.8 "	6 09 "
25	12 28.1	− 1 56	6 14 "	12 08.9 P. M.	6 04 "
Oct. 5	13 28.3	− 9 21	7 04 "	12 29.7 "	5 55 "
15	14 25.8	−15 46	7 50 "	12 47.8 "	5 46 "
25	15 21.7	−20 47	8 29 "	1 04.1 "	5 39 "

VENUS.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5	13 01.9	− 6 16	8 24 A. M.	2 01.3 P. M.	7 39 P. M.
15	13 46.2	−11 13	8 49 "	2 06.2 "	7 21 "
25	14 31.7	−15 46	9 14 "	2 12.2 "	7 10 "
Oct. 5	15 18.8	−19 43	9 40 "	2 19.9 "	7 10 "
15	16 07.6	−22 53	10 04 "	2 29.2 "	6 54 "
25	16 57.8	−25 04	10 26 "	2 39.9 "	6 54 "

MARS.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5	10 56.2	+ 7 57	5 24 A. M.	11 58.3 A. M.	6 32 P. M.
15	11 19.8	+ 5 26	5 19 "	11 42.5 "	6 06 "
25	11 43.4	+ 2 53	5 13 "	11 26.7 "	5 40 "
Oct. 5	12 07.0	+ 0 16	5 07 "	11 10.9 "	5 14 "
15	12 30.7	− 2 23	5 02 "	10 55.3 "	4 48 "
25	12 54.5	− 4 56	4 57 "	10 39.7 "	4 23 "

JUPITER.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
Sept. 5	3 57.0	+19 22	9 30 P. M.	4 53.9 A. M.	12 17 P. M.
15	3 58.2	+19 24	8 52 "	4 15.8 "	11 39 A. M.
25	3 58.0	+19 22	8 13 "	3 36.3 "	11 00 "
Oct. 5	3 56.4	+19 17	7 32 "	2 55.4 "	10 18 "
15	3 53.5	+19 08	6 51 "	2 13.2 "	9 35 "
25	3 49.5	+18 55	6 09 "	1 29.9 "	8 51 "

SATURN.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
Sept. 5	12 47.1	− 2 36	7 54 A. M.	1 46.6 P. M.	7 39 P. M.
15	12 51.4	− 3 04	7 21 "	1 11.5 "	7 02 "
25	12 55.8	− 3 32	6 48 "	12 36.5 "	6 25 "
Oct. 5	13 00.0	− 3 59	6 15 "	12 01.7 "	5 48 "
15	13 04.3	− 4 26	5 42 "	11 26.9 A. M.	5 12 "
25	13 08.8	− 4 53	5 09 "	10 52.1 "	4 35 "

URANUS.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
Sept. 5	14 22.3	−13 44	10 15 A. M.	3 21.5 P. M.	8 28 P. M
15	14 24.1	−13 53	9 38 "	2 44.0 "	7 50 "
25	14 26.0	−14 03	9 01 "	2 06.6 "	7 12 "
Oct. 5	14 28.2	−14 14	8 25 "	1 29.6 "	6 34 "
15	14 30.5	−14 25	7 48 "	12 52.5 "	5 56 "
25	14 32.9	−14 37	7 12 "	12 15.5 "	5 19 "

NEPTUNE.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
Sept. 5	4 49.4	+20 55	10 16 P. M.	5 46.1 A. M.	1 17 P. M.
15	4 49.5	+20 55	9 36 "	5 06.9 "	12 38 "
25	4 49.4	+20 55	8 57 "	4 27.5 "	11 58 "
Oct. 5	4 49.0	+20 54	8 17 "	3 47.8 "	11 19 "
15	4 48.4	+20 52	7 38 "	3 07.9 "	10 38 "
25	4 47.7	+20 51	6 58 "	2 27.9 "	9 58 "

THE SUN.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
Sept. 5	10 58.6	+ 6 33	5 29 A. M.	11 58.4 A. M.	6 28 P. M.
15	11 34.6	+ 2 45	5 41 "	11 54.9 "	6 09 "
25	12 10.5	− 1 09	5 52 "	11 51.4 "	5 50 "
Oct. 5	12 46.7	− 5 02	6 04 "	11 48.2 "	5 32 "
15	13 23.6	− 8 48	6 17 "	11 45.7 "	5 14 "
25	14 01.6	−12 22	6 30 "	11 44.1 "	4 58 "

Phases and Aspects of the Moon.

		d	h m	
Last Quarter	Sept.	3	3 42	A. M.
Perigee	"	4	3 30	"
New Moon	"	10	1 05	"
Apogee	"	17	8 18	"
First Quarter	"	17	10 19	P. M.
Full Moon	"	25	2 23	"
Perigee	"	29	9 48	A. M.
Last Quarter	Oct.	2	9 19	"
New Moon	"	9	2 27	P. M.
Apogee	"	15	4 00	A. M.
First Quarter	"	17	5 20	P. M.
Full Moon	"	25	1 28	A. M.
Perigee	"	27	12 30	"
Last Quarter	"	31	4 42	P. M.

Phenomena of Jupiter's Satellites.

	h	m			
Sept. 1	12	28	A. M.	II	Ec. Re.
	12	58	"	II	Oc. Dis.
	3	15	"	II	Oc. Re.
2	9	23	P. M.	II	Tr. Eg.
3	4	00	A. M.	I	Sh. In.
4	1	11	"	I	Ec. Dis.
	10	29	P. M.	I	Sh. In.
	11	50	"	I	Tr. In.
5	12	41	A. M.	I	Sh. Eg.
	2	01	"	I	Tr. Eg.
	11	09	P. M.	I	Oc. Re.
7	3	06	A. M.	III	Ec. Dis.
8	12	51	"	II	Ec. Dis.
	3	05	"	II	Ec. Re.
	3	30	"	II	Oc. Dis.
9	9	18	P. M.	II	Sh. Eg.
	9	37	"	II	Tr. In.
	11	53	"	II	Tr. Eg.
10	10	42	"	III	Tr. In.
11	12	02	A. M.	III	Tr. Eg.
	3	05	"	I	Ec. Dis.
12	12	22	"	I	Sh. In.
	1	41	"	I	Tr. In.
	2	35	"	I	Sh. Eg.
	3	52	"	I	Tr. Eg.
	9	33	P. M.	I	Ec. Dis.
13	1	00	A. M.	I	Oc. Re.
	9	03	P. M.	I	Sh. Eg.
	10	20	"	I	Tr. Eg.
15	3	27	A. M.	II	Ec. Dis.
16	9	33	P. M.	II	Sh. In.
	11	54	"	II	Sh. Eg.
17	12	06	A. M.	II	Tr. In.
	2	21	"	II	Tr. Eg.
	9	13	P. M.	III	Sh. In.
	10	57	"	III	Sh. Eg.
18	2	28	A. M.	III	Tr. In.
	3	46	"	III	Tr. Eg.
	9	28	P. M.	II	Oc. Re.
19	2	17	A. M.	I	Sh. In.
	3	31	"	I	Tr. In.
	11	27	P. M.	I	Ec. Dis.
20	2	50	A. M.	I	Oc. Re.
	8	45	P. M.	I	Sh. In.
	9	58	"	I	Tr. In.
	10	57	"	I	Sh. Eg.
21	12	09	A. M.	I	Tr. Eg.
	9	17	P. M.	I	Oc. Re.
24	12	09	A. M.	II	Sh. In.
	2	30	"	II	Sh. Eg.
	2	32	"	II	Tr. In.
25	1	13	"	III	Sh. In.
	2	57	"	III	Eg. Sh.
	9	34	P. M.	II	Ec. Re.
	9	38	"	II	Oc. Dis.
	11	53	"	II	Oc. Re.
26	4	11	A. M.	I	Sh. In.
27	1	21	"	I	Ec. Dis.
	10	39	P. M.	I	Sh. In.
	11	47	"	I	Tr. In.
28	12	51	A. M.	I	Sh. Eg.
	1	58	"	I	Tr. Eg.
Sept 28	9	00	P. M.	III	Oc. Re.
	11	06	"	I	Oc. Re.
Oct. 1	2	45	A. M.	II	Sh. In.
2	9	55	P. M.	II	Ec. Dis.
3	2	15	A. M.	II	Oc. Re.
4	8	23	P. M.	II	Tr. Eg.
5	12	33	A. M.	I	Sh. In.
	1	34	"	I	Tr. In.
	2	45	"	I	Sh. Eg.
	3	45	"	I	Tr. Eg.
	8	36	P. M.	II	Ec. Re.
	9	44	"	I	Ec. Dis.
	11	19	"	III	Oc. Dis.
6	12	32	A. M.	III	Oc. Re.
	12	53	"	I	Oc. Re.
	8	01	P. M.	I	Tr. In.
	9	14	"	I	Sh. Eg.
	10	12	"	I	Tr. Eg.
10	12	30	A. M.	II	Ec. Dis.
11	8	29	P. M.	II	Tr. In.
	9	00	"	II	Sh. Eg.
	10	44	"	II	Tr. Eg.
12	2	27	A. M.	I	Sh. In.
	3	21	"	I	Tr. In.
	4	39	"	I	Sh. Eg.
	11	07	P. M.	III	Ec. Dis.
	11	38	"	I	Ec. Dis.
	12	37	"	III	Ec. Re.
13	2	48	A. M.	I	Oc. Re.
	2	48	"	III	Oc. Dis.
	4	00	"	III	Oc. Re.
	8	55	P. M.	I	Sh. In.
	9	47	"	I	Tr. In.
	11	08	"	I	Sh. Eg.
	11	58	"	I	Tr. Eg.
14	9	06	"	I	Oc. Re.
17	3	05	A. M.	II	Ec. Dis.
18	9	17	P. M.	II	Sh. In.
	10	49	"	II	Tr. In.
	11	37	"	II	Sh. Eg.
19	1	04	A. M.	II	Tr. Eg.
	4	21	"	I	Sh. In.
20	1	32	"	I	Ec. Dis.
	3	07	"	III	Ec. Dis.
	4	25	"	I	Oc. Re.
	4	37	"	III	Ec. Re.
	8	02	P. M.	II	Oc. Re.
	10	50	"	I	Sh. In.
	11	33	"	I	Tr. In.
21	1	02	A. M.	I	Sh. Eg.
	1	44	"	I	Tr. Eg.
	8	01	P. M.	I	Ec. Dis.
	10	52	"	I	Oc. Re.
22	7	30	"	I	Sh. Eg.
	8	10	"	I	Tr. Eg.
23	7	00	"	III	Sh. Eg.
	8	07	"	III	Tr. In.
	9	20	"	III	Tr. Eg.
25	11	53	"	II	Sh. In.
26	1	06	A. M.	II	Tr. In.
	2	14	"	II	Sh. Eg.
	3	21	"	II	Tr. Eg.

Oct. 27	3 27 "	I	Ec. Dis.		7 12 P. M.	I	Sh. In.
	6 58 P. M.	II	Ec. Dis.		7 43 "	I	Tr. In.
	10 18 "	II	Oc. Re.		9 24 "	I	Sh. Eg.
28	12 44 A. M.	I	Sh. In.		9 54 "	I	Tr. Eg.
	1 17 "	I	Tr. In.	30	7 02 "	I	Oc. Re.
	2 56 "	I	Sh. Eg.		9 14 "	III	Sh. In.
	3 28 "	I	Tr. Eg.		11 00 "	III	Sh. Eg.
	9 55 P. M.	I	Ec. Dis.		11 20 "	III	Tr. In.
29	12 36 A. M.	I	Oc. Re.	31	12 39 A. M.	III	Tr. Eg.

Configuration of Jupiter's Satellites at Midnight Central Time.

Date	Configuration
Sept.	
1	1 4 ○ 2 3
2	2 ○ 1 4 3
3	2 1 3 ○ 4
4	3 ○ 1 2 4
5	3 ○ 2 4 ●
6	2 3 1 ○ 4
7	2 ○ 1 3 4
8	1 ○ 2 4 3
9	♃ ○ 4 1 3
10	♃ 2 4 1 ○
11	4 3 ○ 1 2
12	4 3 ○ 2 ●
13	4 3 2 1 ○
14	4 2 ○ 1 3
15	4 1 ○ 2 3
16	4 ○ 2 1 3
17	2 4 1 ○ 3
18	3 ○ 4 2 1
19	3 1 ○ 2 4
20	♃ 3 2 ○ 4
21	2 ○ 1 3 4
22	1 ○ 2 3 4
23	○ 2 1 3 4
24	2 1 ○ 3 4
25	3 ○ 1 4 ●
26	3 1 ○ 4 2
27	3 4 2 ○ 1
28	4 2 ○ 1 3
29	4 1 ○ 2 3
30	4 ○ 2 1 3
Oct.	
1	4 2 1 ○ 3
2	4 3 2 ○ 1
3	3 4 1 ○ 2
4	3 4 2 ○ 1
5	2 3 ○ 4 ●
6	1 ○ 2 3 4
7	○ 1 2 3 4
8	2 1 ○ 3 4
9	3 2 ○ 1 4
10	3 1 ○ 2 4
11	♃ 3 ○ 1 4
12	2 3 1 ○ 4
13	♃ 4 ○ 2 3
14	4 ○ 1 2 3
15	4 2 1 ○ 3
16	4 2 3 ○ 1
17	4 3 1 ○ 2
18	4 3 ○ 2 1
19	4 2 3 1 ○
20	4 ○ 1 2 3
21	4 ○ 2 3 ●
22	2 1 ○ 4 3
23	2 3 ○ 1 4
24	3 1 ○ 2 4
25	3 ○ 2 1 4
26	2 3 1 ○ 4
27	○ 1 3 4●
28	○ 2 4 3●
29	2 1 ○ 4 3
30	♃ 2 4 ○ 1
31	4 3 1 ○ 2

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Sept. 23	74 Aquarii	6.0	7 39	39	8 52	255	1 13
24	24 Piscium	6.1	15 42	17	16 31	276	0 49
28	δ Arietis	4.0	8 26	63	9 19	243	0 53
28	τ^1 Arietis	5.0	13 32	34	14 41	265	1 09
Oct. 1	49 Aurigæ	5.7	15 17	113	16 28	241	1 11
2	ν Geminorum	4.3	14 03	35	14 39	327	0 36
17	b Sagittarii	4.6	5 06	134	5 53	194	0 47
20	56 Aquarii	6.3	5 41	82	6 55	213	1 14
21	ψ^1 Aquarii	4.1	3 58	80	5 01	224	1 03
23	ζ Piscium	4.8	16 42	44	17 33	266	0 51
26	36 Tauri	6.0	15 48	105	16 51	227	1 03

Minima of Variable Sars of the Algol Type.

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl. .... $+81°\ 17'$
Period .... $2d\ 11^h 50^m$

Sept. 4	9 P. M.
9	8 "
14	8 "
19	8 "
24	7 "
29	7 "

U CEPHEI, CONT.

Oct. 4	7 "
9	6 "
12	6 A. M.
14	6 P. M.
17	6 A. M.
19	6 P. M.
22	6 A. M.
27	6 "

ALGOL.

R. A. .... $3^h\ 1^m\ 1^s$
Decl. .... $+40°\ 32'$
Period .... $2d\ 40^h 49^m$

Sept. 15	3 A. M.
17	midn.
20	9 P. M.
23	6 "
Oct. 5	5 A. M.
8	2 "

ALGOL, CONT.

Oct.	10	11 P. M.
	13	8 "
	28	4 A. M.
	30	midn.

λ TAURI.

R. A. .... $3^h\ 54^m\ 35^s$
Decl. .... $+\ 12°\ 11'$
Period .... $3d\ 22^h\ 52^m$

Oct.	18	6 A. M.
	22	5 "
	26	3 A. M.
	30	2 "

R. CANIS MAJORIS

R. A. .... $7^h\ 14^m\ 30^s$
Decl. .... $-\ 16°\ 11'$
Period .... $1d\ 3^h\ 16^m$

Sept.	1	4 A. M.
	9	3 "
	10	6 "
	17	2 "
	18	5 "
	26	4 "
	27	7 "
Oct.	4	3 "
	5	6 "
	12	2 "
	13	5 "
	21	4 "

R. CANIS MAJ, CONT.

Oct.	22	7 A. M.
	29	3 "
	30	6 "

U CORONÆ.

R. A. .... $15^h\ 13^m\ 43^s$
Decl. .... $+\ 32°\ 03'$
Period .... $2d\ 10^h\ 51^m$

Sept.	8	midn.
	15	10 P. M.
	22	7 "
Oct.	23	9 "
	30	7 "

U OPHIUCHI.

R. A. .... $20^h\ 47^m\ 40^s$
Decl. .... $+\ 34°\ 15'$
Period .... $1d\ 11^h\ 57^m$

Sept.	1	10 P. M.
	2	6 "
	6	10 "
	7	6 "
	11	11 "
	12	7 "
	17	8 "
	22	8 "
	27	9 "
Oct.	2	10 "
	3	6 "
	7	11 "

U OPHIUCHI, CONT.

Oct.	8	7 P. M.
	13	8 "
	18	8 "
	23	9 "
	29	10 "
	30	6 "

Y CYGNI

R. A. .... $20^h\ 47^m\ 40^s$
Decl. .... $+\ 34°\ 15'$
Period .... $1d\ 11^h\ 57^m$

Sept.	2	3 A. M.
	5	3 "
	8	3 "
	11	3 "
	14	3 "
	17	3 "
	20	3 "
	23	2 "
	26	2 "
	29	2 "
Oct.	2	2 "
	5	2 "
	8	2 "
	11	2 "
	14	2 "
	17	2 "
	20	2 "
	23	2 "
	26	1 "
	29	1 "

COMET NOTES.

Comet *b* 1893.—The account of the discovery of this comet and description of its appearance is given by Professor Payne on page 596. The elements of its orbit thus far computed indicate that it is a new comet and that the orbit does not differ appreciably from a parabola. We have at hand three sets of elements, the first by Professor Boss from observations at Cambridge July 10 and Cincinnati July 11, and a rough observation at Albany July 16; the second by Professor Porter from his own made July 10, 13 and 16; the third by Leavenworth and Wilson from observations at Cambridge July 10 and Northfield July 12 and 14. The last, although depending on shorter intervals of time, appears to be the most accurate, and represents an observation made here July 21 within less than 1′. We have therefore computed the following ephemeris from elements III:

Elements of Comet b, 1893.

	I	II	III	
	Boss.	Porter.	Leavenworth and Wilson.	
T	= 1893, July 7.7520	July 7.3766	July 7.2429 Gr. M. T.	
ω	= 46° 54′	47° 05′.2	47° 11′ 24″	1893.0
Ω	= 335 56	337 02 .2	337 29 17	1893.0
i	= 159 53	159 55 .6	159 59 08	1893.0
$\log q$	= 9.83136	9.82936	9.828890	
C – O	$\Delta\lambda_2 \cos\beta_2 - 0'.5$; $\Delta\beta_2 - 0'.7$		$\Delta\lambda_2 \cos\beta_2 + 9''$; $\Delta\beta_2 + 8''$	

Ephemeris of Comet b, 1893.

Berlin Midn.	R. A.			Decl.		log *r*	log *ρ*	Br.
	h	m	s	°	′			
Aug. 1.5	12	00	58	+ 15	38.3	9.9294	0.0593	0.088
5.5	12	06	23	13	39.8	9.9542	0.1117	0.062
9.5	12	10	25	12	04.8	9.9788	0.1570	0.045
13.5	12	13	38	10	46.9	0.0033	0.1964	0.033
17.5	12	16	16	9	41.2	0.0269	0.2308	0.025
21.5	12	18	36	8	44.4	0.0497	0.2611	0.020
25.5	12	20	42	7	54.4	0.0718	0.2881	0.016
29.5	12	22	40	7	09.8	0.0929	0.3120	0.013
Sept. 2.5	12	24	32	6	29.4	0.1132	0.3334	0.011
6.5	12	26	20	+ 5	52.4	0.1326	0.3525	0.009

The brightness of the comet on July 10 was taken as 1.00.

From this ephemeris it is apparent that the comet is rapidly receding from the Earth and therefore diminishing in brightness. It will probably not be observable in September because of its faintness and the presence of strong twilight.

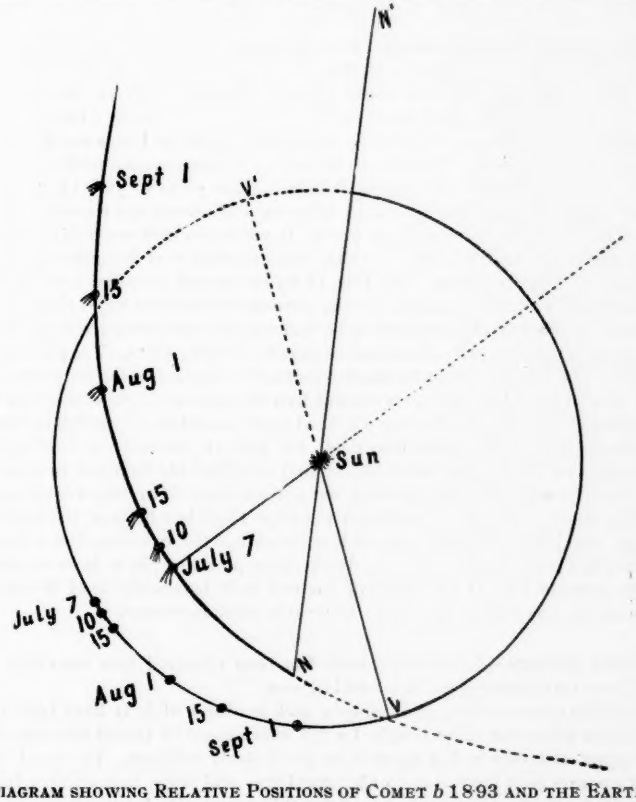

Diagram showing Relative Positions of Comet *b* 1893 and the Earth.

The accompanying diagram will give the unscientific reader some idea of the relation between the paths of the comet and Earth. Suppose the circle represent

ing the Earth's orbit to lie in the plane of the paper, then the comet's path lies in a plane inclined 20° to that of the paper and intersecting the latter in the line NN' which is called the line of nodes.

About June 26 the comet passed the point N, its ascending node, and since that time its path has been north of the ecliptic. On July 7, it reached its nearest point to the Sun, and at almost the same time its nearest point to the Earth. It was discovered therefore at the time of its greatest brightness, when it was almost directly between the Earth and the Sun but at some distance above the line joining the two. The tail of the comet was directed toward a point almost directly over the Earth.

The apparent motion of the comet among the stars was very rapid because of its nearness to the Earth. This has been rapidly decreasing as might be expected from the fact that the Earth and comet are moving in opposite directions. Its course has been southeastward passing by the feet of the Great Bear and between Leo and Coma Berenices. During August it will move very slowly southeast from a point 5° east of the star β Leonis toward the double star γ Virginis.

Photographs of Comet *b* 1893. The comet was so low in the northwest that its position was quite unfavorable for photographs, but fairly successful exposures were made at Goodsell Observatory on the nights of July 11, 14, 18, 19 and 20. The instruments used were the 8-inch Clark refractor with third lens, 5-inch guiding telescope and camera with 2½-inch Darlot lenses and about eight inches equivalent focus. The camera with a 4×5 plate covers a field of about 30° diameter of which 20° is fairly well defined. The plate of July 11, reproduced in our frontispiece, was exposed 45 minutes and shows the comet's tail to a length of 12°, where it runs off the plate. It resembles very much Mr. Barnard's photographs of Swift's comet of 1892, in the number and irregular patchy appearance of the streamers. On July 14 we attempted to make two successive exposures of 40^m duration each, for the purpose of detecting rapid changes. Unfortunately the first plate proved to be bad and the atmosphere was so thick for the second that very little of the tail is shown on either plate. The photographs taken on the subsequent dates show remarkable changes in the structure of the tail. The plate of July 18 shows the tail to a distance of about 8° from the head. There are three streamers leaving the head and the middle one, which is the most prominent, afterward divides into four. On July 19 the same, or similar, three streamers are shown, but much fainter and considerably changed in structure. The length is about 7°. On the 20th but one streamer 5° in length is shown.

The photographs with the 8-inch telescope show but little of the tail of the comet. On July 11 and 14 the nucleus, or rather the condensation about the nucleus, is shown large and hazy. In the later photographs it is more starlike. On the plate of July 11 the width of the tail as it leaves the head is nearly as great as the diameter of the coma. Later it is much narrower.

Comet Rordame.—Rordame's comet has been observed here on every clear night since its discovery, when it could be seen.

Position observations, photographs and measures of light have been taken The comet when seen at its best had a tail which could be traced for some 10 or 11 degrees, although it has never been particularly brilliant. The head of the comet appears as a hazy star to the naked eye, and when last seen on July 14 under fairly good conditions, was of the 3d magnitude, being almost exactly equal to α Ursæ Majoris, which by the Harvard Photometry, is 3.1. A few

nights before it was estimated as 3.5 magnitude from a comparison with ι and κ Ursæ Majoris, both being H.P. stars.

In the telescope the comet has a nucleus which is quite stellar in appearance, surrounded by a bright coma which, however, fades off somewhat rapidly. While the head of the comet seems a little brighter than at first, the tail is steadily diminishing in brightness and length. On July 14 it was rather faintly seen with the naked eye, extending for a distance of some over 2 degrees and nearly vertically.

The rapid easterly motion of the comet at first, together with the diminishing twilight, seemed to indicate that the comet might soon be seen to better advantage, but this easterly motion is slowing up, and if, as the orbital calculations show, the comet is about passing perihelion and also receding from the Earth, it seems probable that ere long it may cease to be visible to the naked eye.

O. C. WENDELL.

Harvard College Observatory, July 15, 1893.

Rordame's Comet.—The first intelligence of the appearance of the comet received here was through the daily press, on July 10. The evening of the same day the sky was very clear but the entertainment of visitors—to whom this Observatory is open on every clear evening—prevented me from obtaining an observation of the comet until 10:45, when the circle readings gave for its approximate place R. A. $8^h\ 35^m$, $+46°\ 59'$. At intervals during the earlier part of the evening I had picked it up with the naked eye, as had likewise the good wife and daughter, Anna, who had been watching for it from the verandah of the house. To the naked eye the comet appeared like a star of the 4th magnitude surrounded with nebulosity, and a tail, in the main straight, but curved slightly at the end, five or six degrees in length was easily seen. In the 10-in telescope the head of the comet appeared large with bright condensation but not stellar. The tail was faint and narrow near the head about half the width of the head, and was brighter on the southern side.

The next night, July 11th, the nucleus was somewhat stellar and on July 14 decidedly so, as it was also last night.

On the evening of July 15th there was a fine aurora and the comet showed itself faintly through the auroral glow. One fine feature of this aurora was a magnificent beam or trail of greenish white light streaming upwards from the western horizon past the zenith. The beam was narrow near the horizon and grew much wider near the zenith. It indeed resembled a gigantic comet of the greatest brilliancy, for which it was mistaken by many persons.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., July 19, 1893.

Photographs of Comet *b* 1893. During the period of its greatest brightness, I have secured a number of photographs of this comet, using the Crocker telescope of the Lick Observatory. The objective of this telescope is a portrait lens of nearly six inches aperture and of about 31 inches focal length. The plates were 8×10 inches, coated with an unusually sensitive emulsion by Cramer (Emulsion No. 6715).

The nucleus of this comet, in all the plates, is bright and star-like. The coma is dense and nearly circular, having a diameter of about ¼°. It has short and very faint extensions in directions at right angles to the tail. The tail has been very bright. So far as these observations extend, it was brightest Thursday

evening, July 13. It could then be traced, with the naked eye, fully twelve degrees. In most of the photographs it extends beyond the limits of the plates used, and, from night to night, exhibits marked and interesting changes. Some of these will be noted.

Tuesday, July 11, $9^h\ 00^m$ to $9^h\ 20^m$. This negative shows the comet with a multiple tail. Four distinct branches proceed from the nucleus. The angle included between the outermost branches is approximately 30°. The middle branches are much the brightest, and at some distance from the nucleus they divide into numerous streamers.

Wednesday, July 12, $9^h\ 00^m$ to $10^h\ 12^m$. Four distinct branches of the tail spring from the nucleus and include an angle of about 40°. The central ones are the brightest. The northernmost one is short, 1½° long, and very gradually diminishes in brightness as the distance from the nucleus increases. The one next to it is bright and nearly straight, broadening a little as the distance increases, and fading away at about 7°. The next is the brightest of the branches and the most complicated in structure. It is composed of numerous streamers, which in places appear to be interlacing and in others to offer a somewhat doubtful suggestion of an outward spiral motion. (This is also the case with the photograph of Tuesday, July 18). Fully 9° of this branch is shown on the plate. The remaining branch is short and without special interest.

Thursday, July 13, $9^h\ 10^m$ to $10^h\ 20^m$. The tail has a complicated structure. In it there are several condensations. The distances of the principal ones from the nucleus are approximately 1°.4, 1°.8, 3°.6 and 6°.0. The second of these is much the brightest. It and also the third are sources of secondary streamers, which give the tail a peculiar appearance, somewhat resembling that shown in Professor Barnard's photographs of Swift's comet of last year. All the condensations belong to the central parts of the tail. In the neighborhood of these condensations the streamers are strongly curved. In the other branches they are very straight and the spaces between them unusually clear. The changes have been so great since last night, that the four divisions of the tail, which were then so distinct, are not easily recognizable now.

Friday, July 14, $9^h\ 08^m$ to $10^h\ 28^m$. The tail can be traced 12° on the plate. The peculiar condensations of last night have very nearly disappeared. Throughout, the tail is very much fainter and its brightness diminishes very gradually. Near the coma, there are seven distinct divisions of the tail. Excepting the central ones, they are straight and short.

Saturday, July 15, $8^h\ 45^m$ to $9^h\ 30^m$. Near the coma the tail has several branches of which the central one is brightest, and excepting it, they are very straight. The central branch divides at about 1° from the nucleus, and near this point the streamers composing it are strongly curved. At 6° from the nucleus the tail is about 1° broad.

Sunday, July 16. The description for last night answers very well for the negative of to-night.

Tuesday, July 18, $9^h\ 01^m$ to $10^h\ 21^m$. In contrast with all the previous photographs, the tail is single near the nucleus and very narrow. It widens slowly. At a distance of 1° from the nucleus it divides and the divisions of the tail are formed. The principal branches are unequally bright along their course.

Stanford University, Cal. W. J. HUSSEY.

July 21, 1893.

Comet 1892 VI (Brooks Aug. 28).—This comet was observed here June 12, when it was described as small, round, 20″ in diameter, strongly condensed in the center, 10 magnitude, so that it was quite easy to observe with the 16-inch. It was barely visible with the five-inch finder.

On July 18, a very faint patch of light was seen just 5′ south of the 8 magnitude star S.D.M. — 20°, 4646, the resulting position being R. A. $17^h\ 02^m\ 23^s$; Decl. — 20° 06′. It was impossible to get a micrometer measurement.

Finlay's Comet.—This comet is in the constellation Taurus near the star ζ. It will during August move eastward into the center of the constellation Gemini. It rises from three to four hours before the Sun, but is in pretty strong twilight when it is high enough to observe, so that it is seen with difficulty.

Ephemeris.

1893		α app. h	m	s	δ app. °	′	″	log Δ.	Aberration. m	s
August	5	5	38	7.92	+ 22	48	17.3	0.14265	11	34.2
	6		42	4.43	22	52	51.7	14450		37.2
	7		45	58.93	22	57	2.1	14634		40.1
	8		49	51.40	23	0	48.9	14916		43.0
	9		53	41.82	23	4	12.8	15097		45.9
	10	5	57	30.17	23	7	14.3	15275		48.8
	11	6	1	16.43	23	9	53.9	15451		51.7
	12		5	0.59	23	12	12.3	15625		54.5
	13		8	42.62	23	14	10.0	15797	11	57.3
	14		12	22.52	23	15	47.6	15966	12	0.1
	15		16	0.28	23	17	5.8	16133		2.9
	16		19	35.89	23	18	5.1	16299		5.7
	17		23	9.34	23	18	46.0	16462		8.4
	18		26	40.63	23	19	9.2	16623		11.1
	19		30	9.75	23	19	15.2	16781		13.8
	20		33	36.70	23	19	4.4	16936		16.5
	21		37	1.49	23	18	37.5	17089		19.1
	22		40	24.12	23	17	55.1	17239		21.6
	23		43	44.59	23	16	57.6	17387		24.1
	24		47	2.91	23	15	45.7	17532		26.6
	25		50	19.07	23	14	19.9	17674		29.0
	26		53	33.06	23	12	40.6	17813		31.4
	27		56	44.90	23	10	48.5	17949		33.8
	28	6	59	54.59	+ 23	8	44.1	0.18082	12	36.1

NEWS AND NOTES.

Subscribers will please remember that this journal does not appear for the month of September, that is our second vacation month.

All persons hereafter paying bills due this journal, on account of subscription or advertising, will please make remittances either by post office order, or note, or registered letter, or bank draft. This change on our part is due to the action of banks in the cities near us restricting the use of personal checks.

Honor to Mr. Proctor's Memory.—It will be remembered that the late Richard A. Proctor, known everywhere as one of the distinguished astronomers of the present century, resided in St. Joseph, Mo., for several years, then in Florida, at

which place he contracted the yellow fever, as he was about starting for a trip to Europe. He reached New York and suddenly died there from the above named disease. His remains came into the hands of the undertaker who interred them in his own lot. Edward W. Bok, editor of the *Ladies' Home Journal*, Philadelphia, visited Professor Proctor's resting place in Greenwood Cemetery, Brooklyn, and found it sadly neglected.

He at once called public attention to the matter, and personally consulted with Mr. George W. Childs, the well-known philanthropist and editor of the Philadelphia *Ledger*, on the propriety of raising a fund for the purchase of a suitable lot and the erection of a monument to the memory of one whose reputation in the literary and scientific world was as wide as civilization. Mr. Childs has concluded to himself furnish the necessary means to purchase an eligible lot in Greenwood cemetery and erect a monument to the memory of Professor Proctor, and has authorized Mr. Edward W. Bok to at once carry out his purpose, so no public subscription will be necessary.

Mr. Childs has in his long career performed many noble and charitable acts, but few, we think, that will redound more to his honor.

The daughters of Professor Proctor, Miss Mary and Miss Agnes, who are highly esteemed and honored by St. Joseph people, are especially grateful to Mr. Childs for his generous act.

They are joined in this token of deserved gratitude to Mr. Childs by the large circle of friends and admirers of Mr. Proctor in all the scientific world.

Investigation of the Nautical Almanac Office at Washington.—An investigation of the conduct of the Nautical Almanac Office by Professor Simon Newcomb, which has recently been concluded at Washington, is so unique in some particulars that a brief account of it will not be without interest. The complainant in the case was Dr. Joseph Morrison, who has been the best known of Professor Newcomb's assistants in the preparation of the American Ephemeris since 1881. His principal duties were those of superintending the printing and seeing that all necessary precautions to guard against error were taken. It appears, however, that Professor Newcomb has recently become dissatisfied with the way in which he performed his duties, and last spring requested his resignation. This was refused, and soon after the present administration came into power, Professor Newcomb wrote to the Secretary of the Navy recommending his dismissal. As this communication forms no part of the case under investigation, we cannot state more exactly what the complaint against Dr. Morrison was. The latter responded by writing a very long letter to the Secretary, not only defending himself with great vigor, but making numerous complaints of the management of the office by the superintendent. The following extracts from the letter will not be without interest:

"I am a graduate in arts, medicine and science of three different universities in this country, as well as of a foreign university, and the author of several works and papers on mathematics and astronomy which are well known on both sides of the Atlantic. In 1884 I was elected a fellow of the Royal Astronomical Society of England, a higher position than Professor Newcomb has in that learned society, although I never was in England, nor did I then, nor do I now, know a single individual in the British Islands. I am also a member of other foreign scientific societies. In 1885, when the National University here was re-organized, with President Cleveland as Chancellor, I was appointed professor of chemistry and toxicology, because I am well known in the medical profession as a chemist, having had a long experience in teaching chemistry. When the Civil Service Commission requested the Secretary of the Navy to select an examiner or member of the

board for the examination of those who came under the classified service in all the scientific "bureaus of the Government," such as the Coast Survey, Naval Observatory, etc., I was honored with their confidence and made presiding officer of the Board. I was finally obliged to resign from that board in consequence of the interference of Professor Newcomb with my examination papers, over which he has no control whatever."

The principal complaints against Professor Newcomb were that he had employed the doctor to write several chapters of a mathematical text-book during office hours; that he had charged mistakes against Dr. Morrison for which other computers were responsible; that he had viciously attacked him for correctly stating that the ephemeris of Saturn's satellite had been computed from Professor Hall's tables; that Mr. Loomis, another assistant, had to do only fifteen or twenty minutes' work daily, though he had once attempted to compute the Moon culminations by formulas prepared by the superintendent, which were the most extraordinary productions of a mathematician that ever came under his notice, because each culmination was made to depend on the preceding; that Mr. Loomis was found unable to do the work; that Professor Newcomb had also been guilty of "base treachery" in preventing Dr. Morrison from getting a professorship in a western college; that he spent much of his time at the Johns Hopkins University teaching mathematics and astronomy, to the utter neglect of the Nautical Almanac; that an undue proportion of the office force was spent on certain "Astronomical Papers," about which "you will look in vain for any favorable comment in the foreign scientific journals;" that Dr. Morrison had been unjustly held responsible for errors in the Almanac which were due solely to the fact that he was not furnished with sufficient assistance in making the necessary computations, etc., etc. Dr. Morrison also claimed that since he had been supervising the printing of the Ephemeris, it was freer from errors than the *Berliner Jahrbuch* or the *Connaissance des Temps.*

After some delay secretary Herbert wrote to Dr. Morrison making some remarks upon the case, and requesting his resignation. This letter also was kept out of the case so that we cannot state its contents. It appears, however, to have contained some expressions not to Professor Newcomb's liking, as it called out the following letter from him to the secretary:

NAUTICAL ALMANAC OFFICE, NAVY DEPARTMENT,
Washington, D. C., June 21st, 1893.

SIR:—In a letter of June 15th, addressed to Dr. J. Morrison, Assistant in this office, you refer to certain counter-charges made by him against Professor Newcomb, which appear to you more or less grave. I respectfully request as a matter of justice to all concerned, that you cause these charges to be thoroughly investigated, in such way and by such agency as you may deem best calculated to bring out all the facts to which they relate.

Very respectfully, your obedient servant,
S. NEWCOMB.

Professor U. S. Navy, Supt. Nautical Almanac.

This request was immediately complied with, and Captain McNair, the Superintendent of the Naval Observatory was ordered to make the necessary investigation, with power to send for persons and papers, and examine witnesses under oath. The accounts of the proceedings which we have seen are both meager and uninteresting, and the whole testimony may be summed up by saying that Professor Newcomb denied *in toto* all of Dr. Morrison's allegations so far as they reflected upon his administration of the office. The most comical part of the inquiry was an investigation of the motion of the ecliptic by the methods of a court of law. Dr. Morrison had claimed that certain formulas given him by the superintendent

for computing the position of the ecliptic in 1600, and 2100 relative to the ecliptic of 1850, must necessarily be wrong, because they showed a motion of the ascending node amounting to nearly 180 degrees which was impossible in 500 years. Professor Newcomb retorted thnt he wanted no better proof of the obtuseness for which he had reported Dr. Morrison than this. The Doctor insisted on expert evidence, and called in Professor Harkness, who however sustained the correctness of Professor Newcomb's formula. At latest advices, the investigation has just been concluded, but the report of Captain McNair's conclusions will probably not be known until after we go to press with the present number.

Columbia College Lectures on "Celestial Mechanics."—Professor J. K. Rees' department of Geodesy and Practical Astronomy at Columbia College, New York City, informs us that arrangements have been made for an extended course of lectures on the general subject of Celestial Mechanics, to be given by Dr. G. W. Hill, member of the National Academy of sciences, Honorary doctor of sciences of the University of Cambridge, England, etc.; that this proposed course will begin about October 14, and continue on Saturdays. These lectures are free and the course will consist, probably at least, of thirty in number. They will be confined to the motions of the heavenly bodies considered as material points, and Dr. Hill thinks it probable that he will not be able to present the whole subject during the remaining months of this year. He prefers to give a somewhat full discussion of the theme rather than a rapid *resume* of it. Short numerical illustrations will be given enabling the hearer to comprehend the bearing of the principles to be applied in practical work.

Dr. Hill has himself kindly furnished the following as a statement of the divisions of his lecture course:

I. General Equations of Dynamics.
II. Derivation of Gravitation from Phenomena.
III. Differential Equations of a System under the action of Gravitation.
IV. The Theory of Elliptic Motion.
V. Perturbations as Variations of Coördinates
VI. Perturbations as Variations of Elliptic Functions.
VII. Hansen's Method.
VIII. Delaunay's Method.
IX. Gylden's Method.
X. Development of the Perturbative Function.
XI. Secular Perturbations in Particular.
XII. The Lunar Theory in Particular.
XIII. The Theory of the Satellites.
XIV. Stability of the Motion of Planetary Systems.

The Columbia people may consider themselves fortunate in being able to secure Dr. Hill for such a course of lectures, and we congratulate Professor Rees on the inception of such a plan of instruction. He has certainly attacked a hard phase of mathematical astronomy for the student, in a wise and most effective way.

Astronomy in Current Periodicals.—*Knowledge* is one of the best periodicals of its kind in the English language. Those interested in the progress of Astronomy and kindred topics will always find its pages well filled with late and useful information. In the July number will be found a full page exquisite engraving of the central portion of the Moon when 136 hours old. It is by the direct photo-engraving process from a photograph taken by MM. Paul and Prosper Henry, with the 13-inch refractor, at the Paris Observatory, March 23, 1893. The sensitive plate was placed behind the eye-piece which enlarged the image in the prin-

cipal focus sixteen times. The center of the plate shows the region between *Mare Nectaris* and *Mare Tranquilitatis*. *Mare Fecunditatis* is also partly seen and there are more than fifty other lunar objects in the area shown that may be recognized by those acquainted with the surface markings. Mr Ranyard's accompanying article on the "Great Plains of the Moon gives a cut showing the principal features in outline, with their names, and explanations of the varied phenomena that will certainly interest any reader. Mr. Sadler's "Face of the Sky" is always very helpful for those who would know about important current celestial phenomena.

The Physical Review is a new publication issued bi-monthly at $3 per year, and is published for Cornell University by Messrs. Macmillan & Company, of New York City and London. Its editors are Edward L. Nichols and Ernest Merritt, of Cornell University, Ithaca, N. Y. Its first number is for July and August and has 80 pp. of original matter devoted to experimental and theoretical physics. The beginning of this new periodical is a very auspicious one in every way and it certainly has a field of usefulness before it.

The particular article that will interest astronomers is the "Relation between the Lengths of the yard and the meter," by Professor William A. Rogers, Shannon Physical Laboratory, Colby University. This important article is supplemental to one found in the Proceedings of the American Academy of Arts and Sciences, for 1882-83, Vol. XVIII. This paper repeats the points in the earlier one, which are valuable as a piece of history of our most common standard, in showing how it was obtained, its probable error, and its relation to other important units of measure. Professor Rogers' work in metrology is an acknowledged authority in this country and abroad.

The Observatory for July contains a noble plate, as frontispiece, of Charles Pritchard, D. D., late Savilian Professor of Astronomy and Director of the University Observatory of Oxford. A biographical sketch is given elsewhere.

Professor E. E. Barnard, of Lick Observatory was present at the meeting of of the Royal Astronomical Society, June 9, 1893, and being called upon, spoke at length, as reported in the *Observatory*, having for his theme, "Photographs of the Milky Way, Comets and other Celestial Objects." His fine pictures were projected on a screen as he described them. A hearty vote of thanks was given Mr. Barnard by the society for his address.

In this number Mr. W. F. Denning describes some characteristics of the Lyrid shower of meteors, also those of Virginids and Aquilids, and Mr. Thos. Gwyn Elger gives full account of the enlarged negative of the lunar Appenines, presented by Professor E. S. Holden, of Lick Observatory.

Publications of the Astronomical Society of the Pacific. No. 30 of Vol. V. is one of the most valuable publications of the society, so far as the illustrations are concerned. The full page plate giving a curve representing the varitions of latitude at Waikiki, Hawaiian Islands, latitude 21° 16′ 24″, covers a period of observation from June, 1891, to July, 1892. The maximum change in that period is about 0″.6. The accompanying article was prepared by E. D. Preston of the U. S. Coast and Geodetic Survey. There are also given four other full page plates, showing the drawings of the surface markings of Mars by Professor Hussey and Professor Schaeberle.

We have been accustomed, in the United States, to speak of Mr. Common's five-foot reflector as if he had made only one speculum of that size. In reality he has ground three of that set. The first of these was found to be defective from faulty glass. The second proved of excellent figure. Another five-foot disc falling into his hands, he proceeded to grind and figure it. In the mean time, being asked to contribute something for exhibition at the World's Fair, he sent speculum No. 2 to Chicago and proceeded to finish No. 3 for his photographic work. This, however, has proved a difficult task and by the middle of June, though the speculum was fairly satisfactory, he decided to regrind and refigure it.

A visit to Dr. Common's home at Ealing, a beautiful suburb of London, is fraught with great interest, and one is impressed with the remarkable mechanical genius that has enabled him to produce his great instruments. This mechanical ability is inherited by a young son of Dr. Common's, who is just now finishing an exquisite working model of an English locomotive.

At a recent visit to Ealing a number of excellent negatives of the great Nebula of Orion, that had been made by five-foot No. 2, were examined. Several of these were remarkably beautiful. The intricate structure of the bright portion of the nebula was brought out in a marvelous manner, while the great looped extensions were also beautifully shown. These negatives did not present the usual 'burnt out' appearance so frequently shown in the bright region of the nebula with long exposures. Every minute detail was clearly shown, up to and about the trapezium. The star discs, though somewhat deformed by irregular 'following' in some of the negatives, indicated a good definition of the mirror. To successfully use these great mirrors, however, takes a mechanical genius and patience not excelled, perhaps, by that required to make the reflector itself.

For photographic work, for such objects as nebulæ, it is a mistake to suppose that these mirrors are not a splendid success.

The new 28-inch Grubb refractor for the Royal Observatory at Greenwich is finished and is now mounted.

It seems regretable that it was necessary to mount this large instrument on the old 12-inch mounting. The focus, 28 feet, is very short for the aperture. The object-glass was figured from curves computed by M. Christy, and is to be photographic as well as visual. By reversing the crown lens the objective is turned into a photographic instrument. It is to be used by Mr. Maunder for spectroscopic observations. The diameter of the dome for this instrument is larger than its sustaining walls, and it has somewhat of a balloon shape, and looks rather oriental.

The photographic zone work of this Observatory is progressing very satisfactorily, a large portion of the zone being already covered.

An examination of some star trails made at Greenwich seems to show that excellent definition is obtained there. This is borne out also by the statements concerning its visual observations. One specially pleasing thing about this great English Observatory is the number of young ladies employed there in the reduction of the work—resembling Harvard College Observatory in this particular.

Among the many interesting things presented at the Royal Astronomical Society rooms is the reflecting telescope with which Sir Wm. Herschel discovered the planet Uranus. It has a very singular mounting and looks extremely antiquated. This telescope produces a reverential feeling, however, and memories of the noble work of Herschel and his sister come upon you as you look at it. The redoubtable Captain Cook's sextant is also preserved in the same room with Herschel's telescope.

The **Ninth Regular Meeting of the Baltimore Astronomical Society** (Astronomical section Maryland Academy of Science) took place at the Maryland Academy of Science on the evening of June 13.

Meeting called to order at 8:15, President Gildersleve presiding.

Minutes of last meeting read and approved. The lecturer of the evening, Mr. Sullivan Pitts, spoke upon The Stars, their magnitudes and distances, distribution of stars and the constellations. Mr. Pitts also exhibited a model that he made, illustrating the joint motion of the Moon and Earth around the Sun.

Reports of observations were then received. Mr. Gildersleve reported spots upon the Sun on all days admitting of observation, and during twenty-three (23) days preceding the meeting there was no day upon which there were not spots upon the Sun. He also called attention to three groups of spots which admitted of continuous observation. Dr. Hooper made statements regarding time of day at which definition of Sun spots was at its best, and gave as his experience that the afternoon was much better than morning, and stated that in the afternoon the atmosphere was much more quiet than in the morning. This statement was partly corroborated by some of the members.

Reports on the Moon and planets and double stars were then in order. Dr. Hooper reported day observations of Venus. Ten minutes were then devoted to general conversation, after which Dr. Hooper (Chairman of Committee on Instruction) appointed Captain Hooper as lecturer for the next meeting, his subject being Nebulæ. Meeting then adjourned to second Tuesday in July.

J. STAHN, Sec'y.

Old and New Astronomy.*—In the preface Mr. Ranyard explains the circumstances under which this work was written. It seems that it was planned by Mr. Proctor many years ago, but financial losses compelled him to give his entire attention to more popular writing and to lecturing. Meanwhile he continued to gather material for the work, and in 1887 its publication was announced. At the time of Mr. Proctor's sudden death in 1888 Part VI had been issued, Part VII was in type, and the chapters on the planets were in manuscript. At this point Mr. Ranyard took up the work, revised the chapters on the planets and completed the book by an exhaustive discussion of the various theories of the Milky Way and the distribution of stars and nebulæ.

Chapter I, on "Ancient and Modern Methods of Observing the Heavenly Bodies," deals in an interesting way with the beginnings of the science. The Egyptologist is informed with some warmth that in questioning the astronomical character of the Great Pyramid he is trespassing outside of his province, and "his opinion is no longer of weight." The ancient observatories at Benares and Delhi are well illustrated and described, as are the instruments of Tycho Brahe and Huyghens. Modern apparatus is then taken up, and the chapter concludes with a full page cut of the 23-inch refractor of the Halsted Observatory. The second chapter on "Ancient and Modern Studies of the Earth's Shape," offers enough proofs of curvature to convert even the most rabid believer in a "flat Earth." Twenty pages are devoted to a discussion of projection and map-drawing, which will be of interest and value to the amateur astronomer. In the succeeding chapter the Sun's apparent motion among the stars is traced in a series of twelve zodiacal maps, and the apparent motions of the Moon and planets are illustrated and clearly described. Chapters IV and V, on "The True Mechanism

* "Old and New Astronomy," by Richard A. Proctor, completed by A. Cowper Ranyard; Longmans, Green & Co., 1892.

of the Solar System," and "Measuring and Weighing the Solar System," are well adapted to the uses of the general reader. Kepler's laws, problems relating to the Moon's motions, the tides, precession and nutation, the Foucault and gyroscope proofs of the Earth's rotation, methods of determining the lunar and solar parallax and the velocity of light, the discovery of Neptune, etc., are explained with but slight appeal to mathematics. The Sun and its surroundings, as well as the principles of spectrum analysis, are dealt with in the two following chapters. Little fault can be found with the descriptive matter, but we imagine that few spectroscopists will assent to Mr. Proctor's explanation of Sun-spots, though the author remarks that it "may be considered established." It is unnecessary to enumerate here the reasons on which is based the conclusion adopted by most spectroscopists, that downward, rather than upward, motions predominate in Sun-spots. Mr. Proctor holds that spots are formed by outrushes of matter which is cooled by expansion. In prominences "the luminous jets and streaks of hydrogen are no more to be regarded as themselves the products of ejection than the luminous streaks behind advancing meteorites are to be regarded as themselves projected through the air" (p. 401). The rays and streamers of the outer corona are attributed to meteoric and cometic matter.

Chapters VIII to XVI inclusive are devoted to the planets and asteroids. In the concluding chapter of 125 pages on "The Stars" we recognize Mr. Ranyard's hand, and are relieved by the absence of the frequently bitter personalities which disfigure the preceding portion of the work. Admirable photogravure illustrations from original photographs of stars and nebulæ, duplicates of which have already delighted the readers of *Knowledge*, are of great value in connection with the text. In the discussion of stellar distribution many novel and valuable ideas are introduced. Rather than assume the existence of dark branching structures in space to account for dark regions partially devoid of stars in the Milky Way we prefer, with Dr. Barnard, to regard the appearances as due simply to irregularities of stellar distribution. Nor can we see in the tree-like forms of nebulæ sufficient reason to believe that the nebulous matter has been shot into a resisting medium. The value of these novel suggestions should not, however, be overlooked; further evidence will probably allow their true importance to be measured.

The book is completed by a table of constants of the solar system, and an excellent index. In typography and illustration the publishers have left nothing to be desired.

BOOK NOTICES.

The Visible Universe. Chapters on the Origin and Construction of the Heavens, by J. Ellard Gore, with stellar photographs and other illustrations. Publishers Crosby, Lockwood and Son, London; Macmillan & Co., New York, pp. 346.

The frontispiece to this new book is a large plate of the great nebula in Andromeda 10 inches by 6½ inches, taken from the original photograph by Isaac Roberts. This beautiful plate is a fitting introduction to one of the most useful books on general astronomy that has been published recently. It is not the object of the author to propound any new hypothesis concerning the origin or structure of the Universe, but rather to explain and discuss theories that have been supported by competent astronomers and other men of science.

The book begins with the Nebular Hypothesis and first presents the views of Kant respecting the Origin of the Universe, as they were advanced by that German philosopher in 1755. Following this and in close comparison with it are the views of the celebrated Laplace, as drawn from his work entitled *Exposition du Systeme du Monde*, published in the year 1796 and further advanced in revisions of the same work published in 1808 and in 1836, although his death occurred in the year 1827. The reader will be interested in this chapter to notice how clearly and well the author has shown the differences of the views of these two great men, who advanced theories so much alike, independently, and from such different lines of investigation. The discussion then proceeds with the views

of later writers who have suggested modifications to the hypothesis, as stated by Laplace; for example, Helmholtz's idea of the Sun's heat, Newcomb, Proctor and Kirkwood's in regard to detached nebulous rings and the long periods of time claimed by the geologists. The objections to the theory as urged by Wolf in his book titled *Les Hypothesis Cosmogoniques* (1886) are presented with fairness and answered clearly and definitely on the basis of modern reasoning and scholarly research.

The second chapter deals with M. Faye's views on the Nebular Hypothesis which seem generally to accord quite nearly with those of the author. Faye's system is presented in detail, and the objections to it are named and discussed. The next step is the theme of *Stellar Evolution* which is introduced by reference to the writings of Dr. Croll, especially those published a short time before his decease, under the title, *Stellar Evolution and its Relations to Geological Time*, (*1889*). Considerable space is given to the consideration of Dr. Croll's so-called "impact" theory and how it is related to that of Laplace, on the one hand, and, on the other, to the later theory, known as the "meteoritic hypothesis" advanced by Mr. Lockyer. In this and subsequent chapters a thorough study is given to the principal points made by Dr. Croll and Professor Lockyer. The "meteoritic hypothesis," and its discussion deservedly assume large space, and the book published by Mr Lockyer under that title in 1890 is here more thoroughly and completely reviewed than has been done elsewhere so far as we know. Chapter VIII s good reading for an epitome of the "meteoritic" hypothesis within the brief pass of forty pages.

The titles of other chapters of this excellent book are, The Fuel of the Sun, The Constitution of Matter, Celestial Chemistry, The Milky Way and Star Distribution, Clustering Stars and Star Streams, Sidereal Distances and Motions, Giant and Miniature Suns, Some Earlier Theories of the Universe, Sir William Herschel's Theories, Sidereal Astronomy from Herschel to Struve, Struve's Theory, Proctor's Views, Infinite Space and a Limited Universe, and an Appendix and a General Index.

The book contains sixteen handsome plates and eleven figures, and they are, many of them new, and well devised for the purpose intended. Attention is especially called to this new book.

Sun, Moon and Stars. Astronomy for Beginners by Agnes Giberne. Preface by Rev. C. Pritchard. New and revised edition, American Tract Society, Publishers, 150 Nassau Street, New York, pp. 334. Price $1.25.

The first edition of this book was published in 1879, and to that edition Professor C. Pritchard (lately deceased), wrote a six page preface commending the book highly. He said "I have often been asked, and, which had as often puzzled me, to the effect, *Can you tell me of any little book on astronomy suited to beginners*?" (The italics belong to the preface). I think that just such a book is here presented to the reader." The reasons for the revision given by the author are, the progressive character of the science, the advancement made in every branch of it during the last decade and especially now since there is a call for an English edition of twenty thousand. Those who have seen the old edition will notice that many old passages have been omitted, and new ones interpolated, large portions of chapters have been rewritten, and that the last two are almost new ones. For the benefit of those who have not seen the edition of 1879, we give below a view in order of the contents by parts and chapters. The first part contains ten chapters as follows:

1. The Earth one of a family. 2. The head of the family. 3. What binds the family together? 4. The leading members of our family—first group. 5. Second group. 6. Our particular friend and attendant. 7. Visitors. 8. Little servants. 9. Neighboring families. 10. Our neighbor's movements.

The second part takes up the same topics as before essentially and gives more concerning each, and the third part has seven chapters with titles as follows:

1. Many Suns. 2. Some particular Suns. 3. Different kinds of Suns. 4. Groups and clusters of Suns. 5. The Milky Way. 6, Reading the light, and 7. Further thoughts.

It is not an easy task to take all these topics and write on them so simply and directly that the popular reader may find what he wants for instruction and entertainment. This author, we believe, has been successful, and we think Professor Pritchard's estimate of the work not overdrawn.

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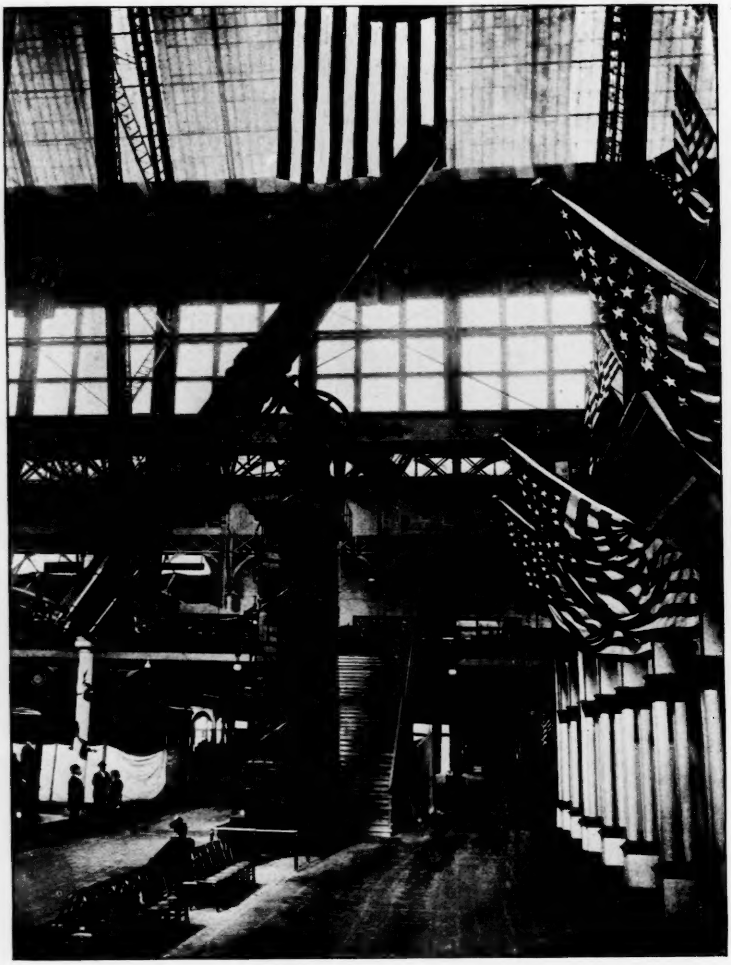

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